foothills
model *forest*
a growing understanding

FOOTHILLS MODEL FOREST
GRIZZLY BEAR RESEARCH PROGRAM
1999 ANNUAL REPORT

Prepared by Gordon Stenhouse and Robin Munro
January 2000

MISSION

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Disclaimer

This report presents preliminary findings from the first year of a proposed 5-year study on grizzly bears in the Yellowhead Ecosystem. It must be stressed that these data are preliminary in nature and represent data collected during the first field season. All findings must be interpreted with caution. Opinions presented are those of the authors and are subject to revision based on the ongoing findings over the course of this study.

Acknowledgements

A program of this scope and magnitude would not be possible without the dedication, hard work and support of a large number of people.

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1999 Foothills Model Forest
Grizzly Bear Research Program
Partners/Sponsors

Foothills Model Forest
Alberta Environment
Canadian Forest Service
Cardinal River Coals
Jasper National Park
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1.0 Introduction

The grizzly bear is considered to be a species whose presence indicates a healthy ecosystem, as such it has been referred to as an "indicator species". Grizzly bears are also considered by some to be an "umbrella" species (Paquet and Hackman 1995). These authors conclude that an additional 403 species were protected by maintaining the habitat needs of grizzly bears, wolves, and lynx. Irrespective of the number of other species involved it is commonly felt that the presence of grizzly bears is indicative of a healthy, functioning ecosystem. It is therefore justified to use the long-term persistence of healthy grizzly bear populations as a barometer with which to measure sustainable land use practices in grizzly bear habitat.

The grizzly bear is a wide ranging, secretive, species, which requires large areas of land in which to meet their life cycle requirements. In response to the demands of hibernation, grizzlies require high quality food in the fall before denning and also after den emergence in the spring. When environmental conditions dictate, grizzly bears search vast areas to meet their nutritional needs. These far ranging movements often results in bears coming into contact with humans, with an associated increase in either direct or indirect bear mortality. The low reproductive rate of grizzly bears and the length of time it takes for them to reach sexual maturity has made it difficult for this species to compensate for increases in natural/human caused mortality with increased productivity. Therefore an increase in mortality, of all types, results in a declining bear population.

In North America, the historic range of the grizzly bear encompassed most of western Canada and the United States. Today, the grizzly bear population in the conterminous U.S. is estimated to be < 1000 (Servheen 1990) and is a high management priority. Even in Canada, where the grizzly bear still occurs in relative abundance, its distribution is largely restricted to remote and mountainous locations (Banci 1991). In Alberta the grizzly bear population is estimated at approximately 850 animals (AEP, 2000) The reduction and fragmentation in bear distribution over the past decade has been primarily attributed to unsustainable mortality rates combined with incremental habitat loss and habitat alienation (McLellan 1999). As human populations and activities expand, associated impacts will increase and result in further fragmentation of bear populations.

West-central Alberta provides about 69% of the current primary range available to grizzly bears in Alberta, and it is thought that this area supports approximately 68% of the estimated current resident provincial grizzly bear population (Nagy and Gunson 1990). This area has been considered to provide the greatest opportunity to increase grizzly bear populations in Alberta through intensive management and conservation programs. However ongoing and increasing human activities in this region raise serious questions about the long-term conservation of grizzly bear and their habitats in this area. As human activities and developments increase within this area so does the likelihood of loss of key habitats, habitat fragmentation and a reduction in the number of security areas for grizzly bears. Recent findings by Benn (1998) have demonstrated that a number of these factors are related to a rise in grizzly bear mortality rates over time. These factors have been shown to result in the regional extirpation of grizzly bears in certain areas of North America (Weaver et al. 1996, Paquet and Hackman 1995).

Although some human activities and development are generally considered harmful to the grizzly population (Servheen 1990, McLellan et al. 1999) they are destined to continue because of the economic value associated with them. Concurrent with development, most people desire the continue existence of the remaining bear population. The challenge facing land managers is to learn how to ensure the long-term survival of this species while addressing human and societal demands on the same land base. If we are to sustain both human use activities and grizzly bears, intensive management based on detailed biological information and a greater understanding of response and interactions is required.

There is considerable historical information about grizzly bears in portions of the current study area. Russell et al. (1979) studied population dynamics of grizzly bears in Jasper National Park (JNP). Part of their study area overlaps the JNP portion of our pilot area. These authors reported bear densities of about 10 bears/1000 km^2. Wielgus and Bunnell (1994) worked in a more southern area of the Rocky Mountain east slopes and estimated grizzly bear density at 16 bears/1000 km^2. Home ranges were large in JNP though females with young had much smaller home ranges and tended to confine their habitat use to upper slopes and side valleys away from adult males (Russell et al. 1979). Our study design reflects the need to achieve reasonable capture success for these females. Nagy et al. (1989) studied grizzly bears in the boreal plains north of Hinton, Alberta, an area which is also north of the present study area. This area is similar to the eastern portion of our study area. They found much lower bear densities, about 5 bears/1000km^2, though they felt the population was declining during the period of study. These authors were unsure if this decline was due to habitat related factors, or other direct factors such as harvest. Based on the above research results, and predictions by Nagy and Gunson (1990), we predict about 50 resident grizzly bears in our study area.

Nagy and Haroldson (1989) analysed seasonal home range and movement patterns for both the JNP and boreal plains studies cited above. They report extremely large annual home ranges for both males and females (roughly 400 km^2 for females without cubs), though females with cubs had smaller average home ranges (250 km^2; n=4 females). They reported that movement distances for these 4 females were reduced by about 33% during spring early summer (15 May-21 July), with respect to their annual home ranges. This suggests spring home ranges for females with young, in the boreal plains part of the study area, may be in the 100-200 km^2 range. No home ranges for females with cubs were presented for JNP, but home range sizes for other bears were similar among the 2 areas (Nagy and Haroldson 1989). We expect home range size for females with cubs will also be similar in the JNP portion of our study area.

2.0 Background

In 1999 The Foothills Model Forest initiated a major 5-year grizzly bear research project. This research program focuses on management issues and questions by assessing grizzly bear populations, bear response to human activities, and habitat conditions to provide land managers with tools to integrate grizzly bear "needs" into the land management

decision making framework. This approach is intended to allow resource managers to gain a better understanding of grizzly bear ecosystems and grizzly bear response to human activities and to implement appropriate actions. Results from this program will be useful for successful grizzly bear management throughout Alberta, and other areas of grizzly habitation throughout North America, as it will provide tools and techniques that address landscape level conservation issues.

3.0 Long Term Program Objectives

To provide resource managers with the necessary knowledge and planning tools to ensure the long-term conservation of grizzly bears in the Yellowhead Ecosystem.

Program Goals:
The knowledge obtained from this study will be used to:

1. Provide information that will support management programs to provide stable/increasing grizzly bear populations over time,
2. Identify habitat and landscape conditions that contribute to or limit viable and regionally connected grizzly bear populations,
3. The development of a set of validated, user friendly, GIS based computer models for the Northern East Slopes Region, that will provide predictive capability when resource managers are making land use planning decisions in known grizzly bear range.

4.0 1999 Key Program Elements

The key elements of the FMF Grizzly Bear Research Project are:

- **Status and Trends:** provide data and develop methodologies to allow managers to assess and monitor grizzly bear population parameters over time (i.e. productivity, survival rates, mortality rates, sex ratios, etc.). These data will also form an integral component concerning model validation and ongoing development. This element will be one indicator used to assess program success.
- **Movements:** gather animal data to document grizzly bear travel corridors within the research study area, document home range patterns and den sites, assess habitat use at a number of spatial and temporal scales, and document bear response to human activities at a landscape scale.
- **Mortality:** monitor and evaluate known grizzly bear mortalities within the study area of both study and non-study animals.
- **GIS:** utilize existing GIS based grizzly bear cumulative effects models in selected research study areas to provide an overview of grizzly bear habitat issues at the current time. These data will be used in research study design and research study area selection. Continue to test and develop these CEA models with animal data collected through the field efforts and to integrate other resource planning tools (forestry, mining, etc.) to allow predictive capability of the effects of changing landscape conditions over time on grizzly bear populations.

- **Communications:** an important element of this program will involve the continued and ongoing communication of research results and program findings to all partners and interested stakeholders. This element will be critical to maintain and enhance the partnerships formed and ultimately will be vital in achieving the program objective.

5.0 Study Area

The research study area encompasses an area of 5352 km2 (Figure 1). Approximately 43% of the research study area falls within Jasper National Park. This fact allows comparisons between portions of the landscape with varying degrees of human use and activity (i.e. inside and outside JNP). Human activities within the study area include a wide variety of land use activities including, but not limited to; hunting, tourism, forestry, mining, oil and gas development and exploration, transportation corridors, trapping, commercial outfitting, and public recreational use. The study area is bounded to the north by Highway 16 and the Athabasca River, to the east by a forestry trunk road, to the

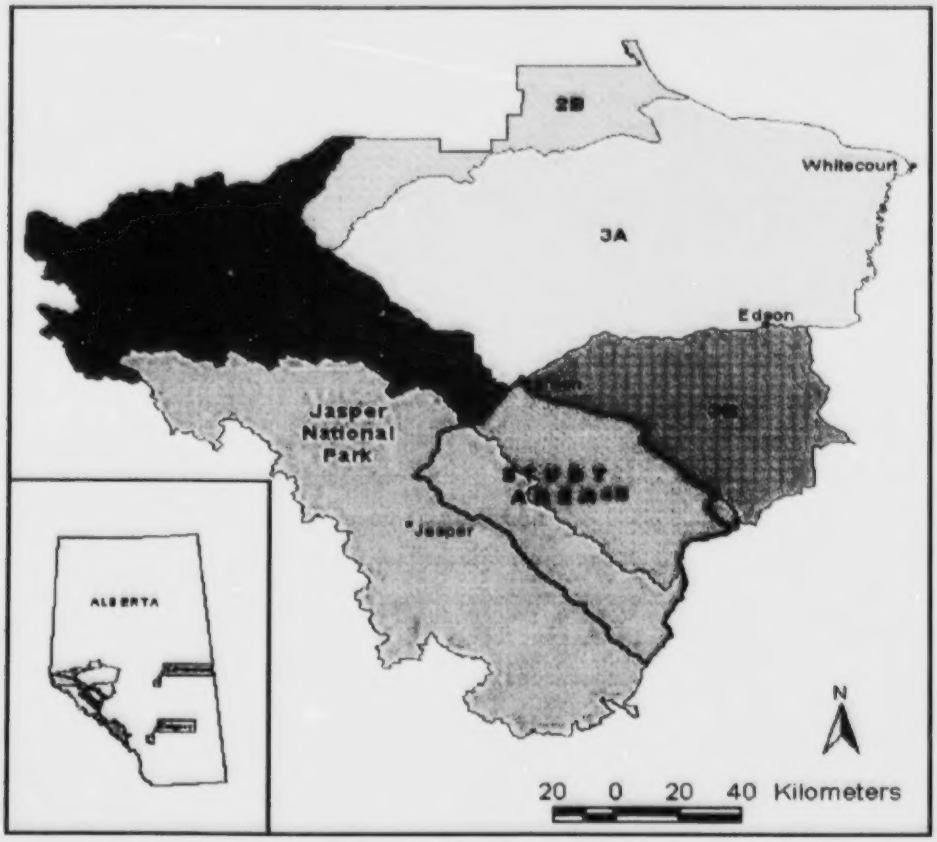


Figure 1. Map of study area

south by the Brazeau River and by a mountain range in Jasper National Park as the western boundary. It was recognized early in the planning process that these boundaries

would not limit bear movement within the study area. Ultimately however, the final boundary delineation of the research study area will be determined by grizzly bear landscape use through data collected from radio telemetry efforts.

The study area is comprised of portions of 5 distinct natural sub-regions. These are: alpine, sub-alpine, montane, upper foothills/sub-boreal spruce, and lower foothills (Figure 2). The proportional representation of these sub-regions is presented in Table 1. We used one component of the FMF WAM (Watershed Assessment Model) procedure to assist in the delineation of watershed units. Based on the approach used by Purves and Doering (1998) we tailored these watershed units within the research study area to approximately conform to a size similar to an adult female grizzly home range (approx. 340km2) (Figure 3). The 16 designated watershed units are referred to as bear management units (BMU's) within the research study area. BMU's previously established for Jasper National Park were incorporated, merged, and in some cases modified for incorporation into the defined BMU's for the research study area.

6.0 Bear Capture and Handling

6.0.1 Methods

In order to collect detailed movement and habitat use data on grizzly bears within the study area, it was necessary to capture, immobilize, and radio collar a sample of the grizzly bear population within the study area. Since the study area presented opportunities for capturing bears in both forested and non-forested habitats we employed two different capture techniques (aerial darting, and leg hold snaring) during the spring capture period. With an overall goal to have at least one collared grizzly bear in each bear management unit, we allocated capture effort across the 16 BMU's. Once a bear was captured within a BMU this unit was considered closed to further capture efforts we then focused additional effort in the remaining BMU's where bears had yet to be captured. The goal of this approach was to distribute radio collars within the research study area in a systematic fashion to avoid biases related to sampling effort.

We had 20 GPS radio collars to deploy on grizzly bears within the research study area. This number of collars was selected based on estimated bear densities within this area, and also based on statistical requirements for data analysis. In an effort to gather data from all cohorts of the population we deployed collars on both male and female bears that were large enough for instrumentation purposes. Small subadult bears were not radio collared, however subadult bears captured as part of a family group were lip tattooed for future identification and in some instances these bears received a VHF ear tag transmitter. All capture efforts taking place in this program followed procedures currently being reviewed and revised by the Canadian Council on Animal Care for the safe handling of bears. In addition this research program adhered to the "Protocol for the use of drugs in Wildlife Management in Alberta" (May 9, 1997) in all aspects of fieldwork involving the capture and handling of grizzly bears. The animal handling protocol was also reviewed

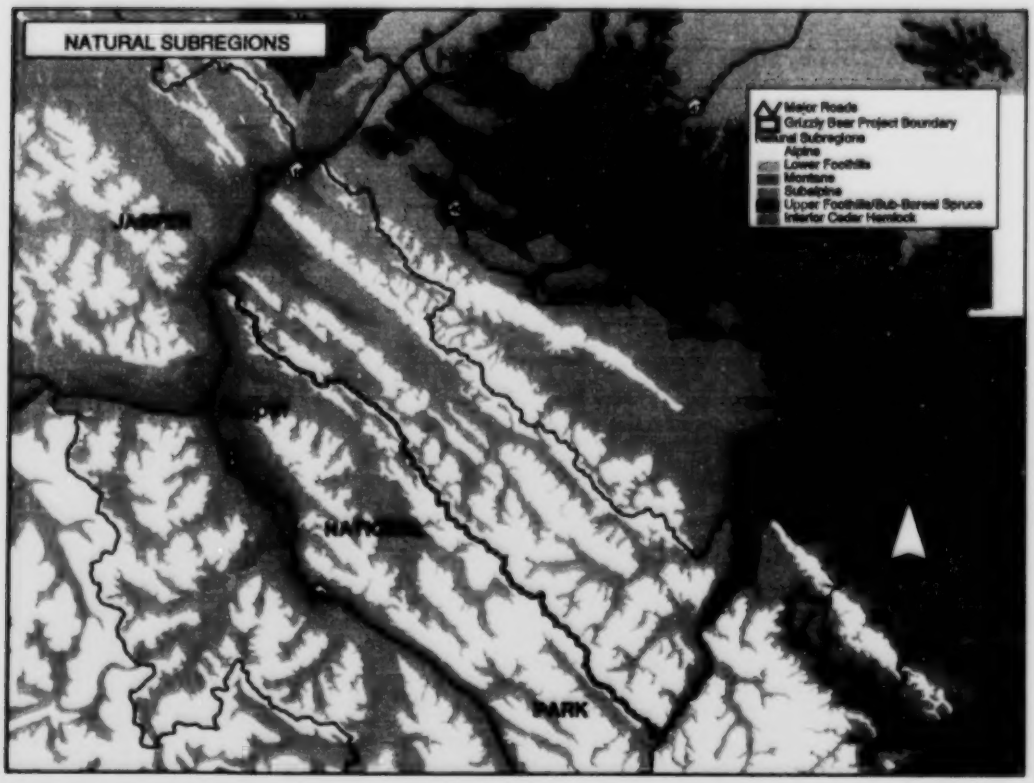


Figure 2. Distribution of natural sub-regions in the study area

Table 1. Natural sub-region composition of grizzly bear research study area.

Sub-regions	% Area	Area (km^2)
Alpine	26	1377
Sub-alpine	48	2555
Montane	1	60
Upper Foothills	4	203
Lower Foothills	22	1156

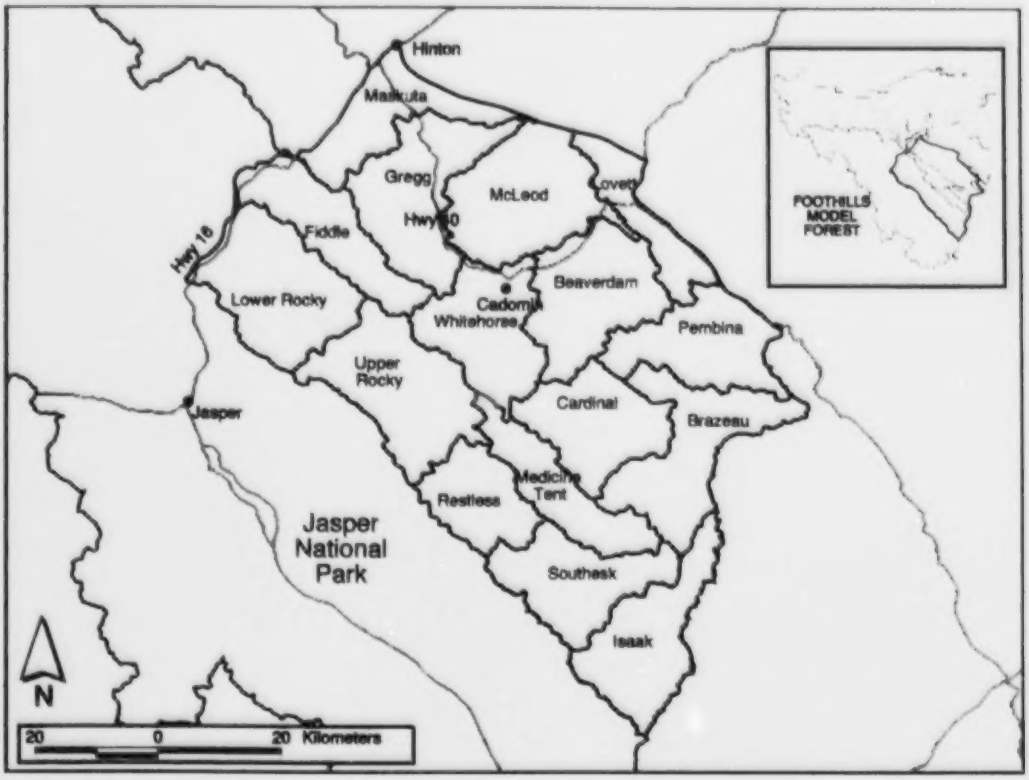


Figure 3. 16 Bear management units with the study area.

and approved by the Animal Care Committee at the Western College of Veterinary Medicine in Saskatoon, SK.

Field Operations

As mentioned we utilized two primary methods to capture grizzly bears within this research program: aerial darting, and snaring.

(a) aerial darting

In an effort to increase capture success in open alpine and sub-alpine areas we located ungulate carcasses from road kills as bait attractants for bears. This technique was designed to attract and potentially hold bears for short time periods that would afford the opportunity to capture them using aerial darting. Our search protocol was to search open areas and bait stations and look for bears and or fresh sign (tracks, scats, etc) with the aid of a Bell 206 helicopter. These search efforts will be limited to open habitats where grizzly bears and their tracks can be seen from the air.

Once a grizzly bear was observed the capture crew determined if the surrounding habitats and geography permitted a safe pursuit and capture. Chase times were limited to less than 1 minute and usually lasted for approximately 30-45 seconds. Full details on the results of bear handling (and blood chemistry/histology) are presented in Appendix A.

Bears were immobilized with one of the standard rifle systems for firing internally charged darts (Palmer or Pneu-dart). Bears were immobilized with either Telazol or Telazol/Xylazine according to weight/dosage table prepared by Dr. Marc Cattet and Dr. Nigel Caulkett. Aerial darting took place from a range of approximately 10-15 m. Once a bear was darted the helicopter and crew moved away from the bear to reduce stress while ensuring that visual contact was maintained. Once the bear was showing signs of immoblization the helicopter landed a safe distance away. Further visual checks were made on the bear from the ground before the capture team approached the bear to ascertain level of immobilization. During the immobilization process and at all times during the handling procedure a person equipped with an appropriate firearm (12 gauge shotgun) stood vigil for the rest of the capture crew. Once it was safe to handle the bear, the field crew placed the bear in a comfortable sternal recumbancy position. Breathing rates and core body temperatures were monitored regularly throughout the handling procedure. Care was taken to ensure that air passages and oral cavities are free and clear to ensure there were no impediments to respiration. All bears had ophthalmic ointment applied to their eyes and blindfolds applied to reduce the risk of eye injury during immobilization. Field crews worked quickly and quietly around bears to minimize stress on the animal.

Captured grizzly bears had GPS collars applied, a VHF ear tag transmitter attached, a premolar tooth removed for aging purposes, lip tattoo's applied, hair samples and fecal samples collected for DNA analysis, and blood samples collected for analysis. All bears were also inspected for any signs of previous capture, injury, and/or physical abnormality. Whenever possible bears were also weighed and a variety of standard

morphological measurements taken. Both topical and IM antibiotics were administered to all bears to minimize the likelihood of infection related to handling procedures. Bears, which were immobilized with the combination of Telazol/Xylazine, received Yohimbine as an antagonist. These bears were watched from a safe distance to record recovery times. In addition, an aircraft overflight was made to check on all captured bears sometime later that same day.

(b) snaring

Ground based snaring operations were conducted in portions of the research study area where aerial darting was not possible. These areas were typically those with dense forest cover occuring to the east of the front ranges of Jasper National Park. One exception to this general protocol occurred in the Lower Rocky BMU within Jasper National Park. In this BMU we had not located and captured a grizzly bear through aerial darting by the end of May. At this time the program partners agreed to proceed with some snaring operations in this BMU in an effort to have one bear collared here.

Snare Construction: Aldrich leg snares were purchased from Margo Supplies, Calgary, AB. The snare components consist of a: spring, ¼" airplane cable for the foot loop and anchor cable, sliding lock, cable clamps, crimps and a swivel. Foot loops required assembly using a combination of cable clamps and crimps. Snares were constructed to lie flat and close as tightly as possible (tested by using the yo-yo technique). To reduce the chance of cable clamp nuts becoming loose, regular nuts were removed and replaced with locking nuts. We found the best snare construction technique consisted of placing a cable clamp on the locking end of the foot loop and a cable crimp on the swivel end. This allowed for easy snare removal from the leg should the cable become jammed in the sliding lock.

Bait Collection: Baits were used to attract grizzly bears to the snare site location. The main source of bait consisted of beaver and ungulate carcasses. Beaver carcasses (approximately 500) were purchased from registered trappers while ungulate carcasses were obtained from road-kills that had occurred in the preceding 3 months prior to the capture period. Bait was kept frozen in freezers until required or transported directly to the trap sites. Large ungulate carcasses were used at sites that were easily accessible by truck. Where access to trap sites was restricted to ATV's or helicopters, beaver carcasses were an ideal bait size.

Trap Site Selection and Construction: Trap site selection was determined from a compilation of information obtained from, trappers, hunters, Fish and Wildlife personnel, Forestry workers and aerial recognizance. Criteria used in the selection of specific trap sites was based on known bear usage, accessibility (helicopter and ground access), safe visual distance (100m minimum) to observe trap site on the ground, environmental hazards to bears after their capture and release (water, topography). Trap site construction included the limbing of tree branches from the anchor tree, clearing trees and brush from the site, and building cubbies. A basic trap site consisted of setting 1 cubby set and 2 – 3 trail sets. The snare's anchor was attached to a live tree (30cm dbh) using the shortest anchor lead possible. All clamp nuts were checked for tightness. Barriers were set up across trails to prevent ungulates from getting caught in snares. Trap

transmitters were occasionally used at sites that only had a single snare. Bait was placed in the cubby, hung in nearby trees and dragged various distances from the trap site. Dragging the bait produced a scent trail for a bear to follow to the trap site. A blended mixture of fish oil, beaver castor and blood was also used as a lure. Trap sites were re-baited as required.

All trap sites were closed to the public. Public notices were place in local newspapers advising of the research underway and the areas which may experience site specific area closures. Closure signs and tape were put up at all trap site access points.

Ground Capture Procedures: Snares were checked as early as possible on a daily basis. A team would access the site on the ground using ATV's or by helicopter. The ground team consisted of two or three experienced personnel. The trap site was observed from a safe distance to determine if a bear had been captured. Usually it was evident when a grizzly bear had been snared (vocalization, excavations, bark torn off trees). When a bear had been captured the following visual observations were made; 1) the trap site and surrounding area was observed to determine if there were any other bears present, and 2) the position of the snare on the bears leg was assessed. With this information the capture team would determine the best approach plan to ensure the safety of personnel and to minimize stress to the animal. With an armed team member on each side of the darter the bear was approached to a safe darting range of 10 to 15m. Once the bear was successfully darted the team retreated to a safe distance to observe the bears reactions to the drug.

After the bear was immobilized the bear was processed (see previous section on aerial darting for processing details). During the processing individual team members had assigned duties. When processing had been completed all other snares in the area where sprung. The team then left the trap site allowing the bear to recover. Bears captured with this technique will be checked on by a helicopter over-flight within 24 hours following capture.

6.0.2 Results

The capture period occurred between April 25 – June 20, 1999. During this time period the capture teams captured and handled a total of 24 grizzly bears and 5 black bears. This included one grizzly bear handling mortality. Only one non-target species was caught in a snare and this was an adult male moose. In total 19 of the captured grizzly bears were radio collared and were used to study bear movements during the first field season. The age and sex of radio collared grizzly bears is presented in Table 2. A further breakdown of captured grizzly bears in relation to age cohort is shown in Table 3. Findings from other grizzly bear research in both Alberta and British Columbia (Gibeau and Herrero 1998 and McLellan 1989) have shown that although the age of sexual maturity does vary among grizzly bears it is generally accepted that 0-4 years is a subadult non breeding animal. Our capture sample of bears included two family groups (both females with 2

Table 2. Age-sex of radio collared bears in the 1999 field season.

Sex	Capture Date	Age
F	99/05/04	17
	99/05/09	5
	99/05/10	5
	99/05/19	3
	99/05/20	12
	99/05/25	13
	99/05/05	6
	99/05/26	5
	99/05/27	4
	99/06/02	5
	99/06/13	4
M	99/05/11	11
	99/05/11	16
	99/05/14	14
	99/06/06	9
	99/05/28	5
	99/05/28	7
	99/05/29	3
	99/06/20	11

cubs). A comparison of bears captured within and outside Jasper National Park is presented in Table 4 and 5.

Table 3. Age class distribution of captured bears from the 1999 field season.

	Males	Females	Total
0-4 yrs	2	4	6
5-10 yrs	3	5	8
11-15 yrs	3	2	5
>15 yrs	1	1	2
Total	9	12	21

Table 4. Total number of grizzly bears handled by age-sex class in the 1999 field season.

	Adults		Subadult		Yearlings		Total
	M	F	M	F	M	F	
Jasper Park	2	4*	1	0	0	0	7
Provincial	5	4**	1	3	2	1	16
Total	7	8	2	3	2***	1	23

*includes one female with 2 yearlings

**includes one translocated female with 1 yearling

***includes one translocated male which maybe second yearling cub of translocated female

Bears were captured in all but one of the 16 designated bear management units. We were not successful in locating a grizzly bear in the Lower Rocky BMU despite attempting both aerial darting and ground based snaring within this area. Figure 4 identifies the sex distribution of collared bears in the BMU's within the study area. This figure also shows which BMU's (Fiddle, McLeod, Lovett, and Brazeau) had two bears captured and radio collared within them. No effort was made to select for specific sex cohorts during our capture efforts.

Table 5. Comparison of bears handled within and outside Jasper Park in 1999.

	Jasper	Province	Total
M	3	9	11
F	4	8	12
Total	7	17	24

7.0 Movement

7.1 Telemetry and Data Collection

7.1.1 Methods

(a) GPS Radio Collars

Some of the key research questions of this study relate to habitat use and grizzly bear response to human activities. These questions require that detailed information be collected on the movements of bears within the research study area. The approach we have taken in this program to acquire this type of data is the utilisation of GPS (global positioning systems) radio collars. These systems allow researchers the opportunity to collect detailed movement data on a 24-hour basis over a 9-10 month period. In the first year of this program we utilized the different brands of GPS radio collars. By using two different brands of GPS radio telemetry equipment we felt that we would be better able to

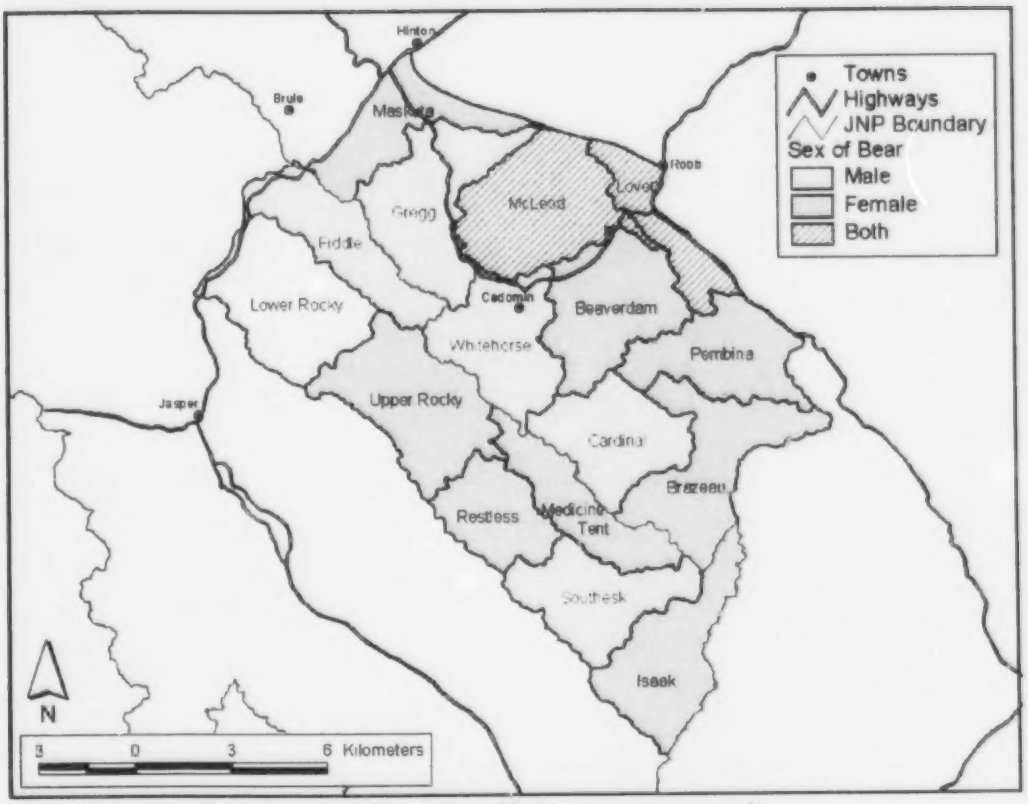


Figure 4. Distribution of bears by sex and bear management unit

maximize data recovery, and to make an assessment of each GPS system in relation to continuing its use in future years.

(i) Televilt GPS radio collars: We deployed 10 Televilt Simplex GPS radio collars (8 channel systems) in the first year of this program. These collars weighed 1.26 kg and were attached with two layers of cotton webbing to act as a "rot off" mechanism in the event that the animal was not recaptured in successive years. Each collar was programmed using the SIMPSET software supplied by Televilt, Sweden. Each collar had a unique GPS signal acquisition schedule, which provided coverage over a 24-hour period every 4 hours (Appendix B). These collars also had a VHF beacon that was active when the GPS system was not receiving a signal. These collars also had the capability to transmit stored data at specific programmed times. We programmed the Televilt collars to transmit stored data on a monthly basis. Each collar had a unique upload time and would repeat the transmission of data on four consecutive days. If data were not collected on any of these four days (poor weather affecting flying, unable to locate bear, etc.) the collar would store the monthly data in permanent memory. This data could only then be recovered by retrieving the collar and downloading the data directly from the collar. Each collared bear also had a VHF ear tag transmitter (Telonics, AZ) attached to one ear. These ear tag transmitters weighed approximately 1.5 oz and were programmed to start transmitting in October 1999. We programmed this schedule in order to reduce the possibility of signal interference when the GPS collars were transmitting data on the VHF frequency. Each ear tag transmitter had a VHF frequency that matched the GPS collar. This approach was taken to reduce the number of frequencies that would have to be monitored during aircraft telemetry flights.

Data files from these collars were converted to a text file which included the following: date, time, Lat/Long, DOP and 2D/3D.

Advanced Telemetry Systems (ATS) GPS radio collars: We also deployed 9 ATS GPS collars which are 12 channel systems produced by ATS, Minnesota. These collars are store on board systems where all GPS data is stored within the memory of the collar and the researcher must recover the collar to download the location data. These collars weighed 1.77 kg and included the Wildlink remote drop off system. This system allows the researcher to remotely trigger the collar to release from the animal and then it can be recovered to retrieve the stored GPS data. All ATS collared bears also had a VHF ear tag transmitter with the transmission schedule described above (see Televilt GPS radio collars). We did not attach the canvass "rot off" to the ATS collars because the Wildlink remote drop off system allowed us to retrieve these collars.

The ATS collars were also programmed to collect a location every 4 hours. In order to collect bear movement at all times during a 24-hour period, each collar also had a unique collection schedule. These collars also had a pre-programmed system that allowed the GPS unit to retry getting a GPS fix every 15 minutes if a location attempt is unsuccessful. This would continue for a maximum of 3 attempts. If no locations were obtained then the unit would revert to the original acquisition schedule.
Data files from ATS collars are converted to a text file which included the following: date, time, UTM, elevation, 2D/3D, DOP and which satellites were acquired to obtain the

fix. Figure 5 shows the distribution of the two types of GPS radio collars across the study area.

(b) Data Uploads, Collar Retrieval and Data Processing

Uploads were required for the Televilt collars only and uploads generally occurred during the last four days of every month. We utilized helicopters to upload data from the GPS Televilt collars, and on some occasions where topography dictated we were able to upload data from the ground. The helicopter uploads required the aircraft to circle the general location of the collared bear for this time period at an altitude of approximately 1500 ft above ground level. Once the uploading was completed the data was downloaded

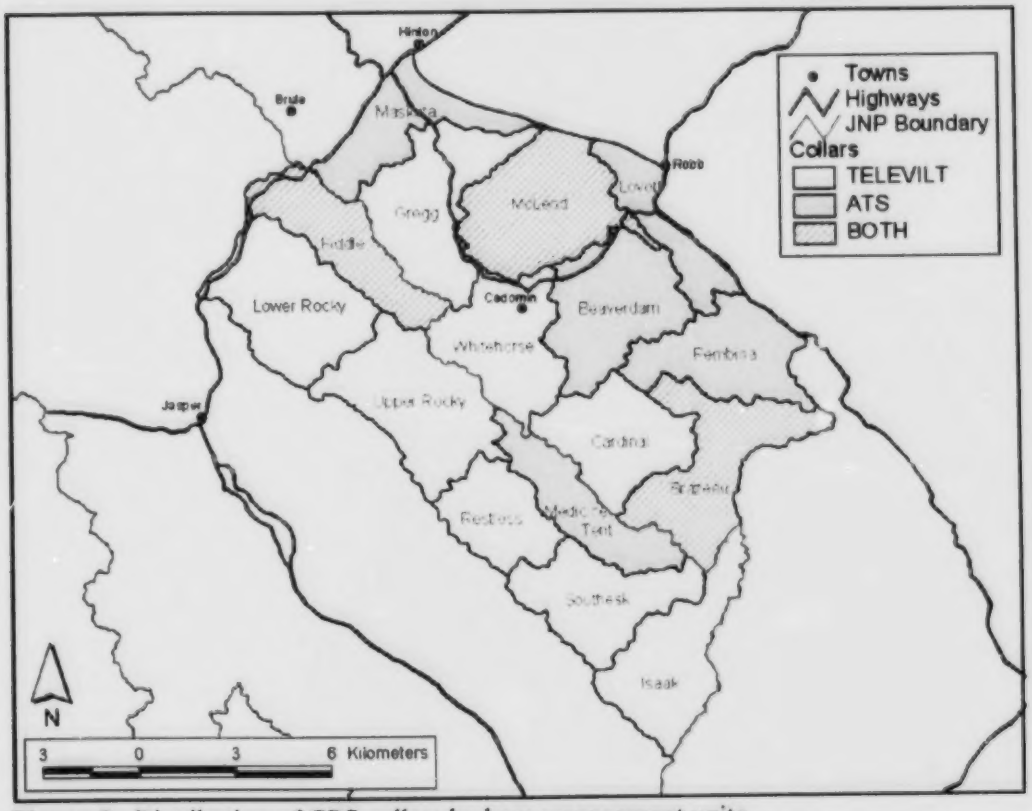


Figure 5. Distribution of GPS collars by bear management units.

to a computer using Televilt's RXD program and then converted to a temp file using Televilt's Simpost program. The temp file was subsequently processed to eliminate obvious errors in the data stream using a text editor and then converted to a text file.

Collars were retrieved whenever we encountered a mortality signal during upload flights. Furthermore, in October a systematic effort was made to retrieve the ATS collars. A fixed-wing aircraft (Cessna 336) was used to locate all the bears. The collar was then retrieved using a helicopter. The data from both the retrieved Televilt and ATS collars

was downloaded directly to the computer and then converted to text files. No post-processing of data was required for data taken directly from the collar.

7.1.2 Results

Of the 19 collars deployed, 12 have been retrieved but only 10 had data, 4 currently remain on bears, and 3 have been lost due to mechanical/electronic failures (Table 6). To date, a total of 5554 locations have been collected from 13 bears, including 7 females and 6 males. This includes all data both from retrieved collars and uploads (Table 7). However, when locations obtained after collar drop off were removed, the total sample size was reduced to 5056 locations. Based on this latter total, the sample size per bear ranged from 25 - 794 locations. This large variation was primarily a result of some bears dropping their collars shortly after capture. Collars remained on the between 7 - 211 days. When both collar types were combined the average number of fixes per day was 3.71. Considered separately, ATS averaged 4.81 fixes/ day, and Televilt averaged 3.23 fixes/day.

A total of 37 uploads were carried out between June 30/99 and Dec 2/99. Multiple uploads were performed on some bears during each reporting period in an attempt to improve the quality of data transmission. Transmissions lasted between 8-17 minutes, depending on the amount of stored data being transmitted. The quality of the transmission was primarily dependent on landscape topography. In general, uploads in wide alpine meadows tended to be more successful then uploads in narrow drainages. The proportion of locations extracted from the report varied between 32-100% with an averaged of 70%. This variation is a result of the quality of data signal that, in turn, was primarily a result of the landscape topography and partially a result of our inexperience with the technique. As our knowledge and experience with the GPS technology increased our ability to obtain better signal transmission improved over time.

7.2 Comparison of Televilt and ATS GPS Collar Types

7.2.1 Methods

The objective was to explore the 1999 results and performances of ATS and Televilt GPS collars in relation to: (1) the mechanical performance of the collar, (2) the success of collars in acquiring a location, (3) the quality of the location acquired as it relates to Dilution of Percision (DOP) values and (4) the frequency of 2D and 3D fixes acquired in areas of different relief. To broadly explore, the location success of collar types, locations from collar data were categorized by bear management units (BMUs) as either inside or outside Jasper Park, i.e. in the mountains or not in

Table 6. Current status of the GPS collars.

	Recovered with data	Recovered with no data	Still on bear	Unknown*	Total
ATS	4	2	0	3	9
Televilt	6	0	4	0	10
Total	10	2	4	3	19

*no VHF beacon because of electrical failure

Table 7. Total number of locations obtained from the GPS collars during 1999.

BearId	Collar Type	Date of capture	Date of drop-off	Total location from collar retrieval/uploads	Total locations before drop-off/denning	No. of days collar on bear	Average no. locations/day*
G001	Televilt	28/04/99	30/06/99	312	248	63	3.94
G002	Televilt	04/05/99	still on (den)	371	371	211**	1.76
G004	Televilt	10/05/99	20/10/99	800	794	163	4.87
G005	Televilt	11/05/99	20/08/99	717	476	101	4.71
G006	Televilt	11/05/99	01/09/99	493	426	113	3.77
G008	Televilt	14/05/99	22/09/99	397	393	131	3.00
G013	Televilt	27/05/99	01/10/99	218	200	127	1.57
G016	Televilt	28/05/99	still on (den)	408	408	187**	2.18
G020	Televilt	13/06/99	still on (den)	554	554	171**	3.24
G003	ATS	09/05/99	16/09/99	619	619	130	4.76
G010	ATS	25/05/99	02/09/99	553	481	100	4.81
G012	ATS	26/05/99	02/06/99	29	25	7	3.57
G017	ATS	28/05/99	07/06/99	83	61	10	6.1***
			Total	5554	5056	1514	mean = 3.71

*total locations before drop off divided by the number of days collar on bear

**collar is still on animal and all the data on the collar has not yet been retrieved.

***collar attempted higher than normal number of fixes per day (6/day) because of faulty electronics

the mountains (Figure 6). Bears with successful locations occurring primarily (>99%) in one "mtn" type (in or out) were used to examine the location success rate. Unsuccessful location attempts for these bears were assumed to be in the same mountain type as the successful locations. To examine DOP and 2D/3D fixes, only successful locations collected while the collar was on were considered. Upload data was used where collar data was unavailable.

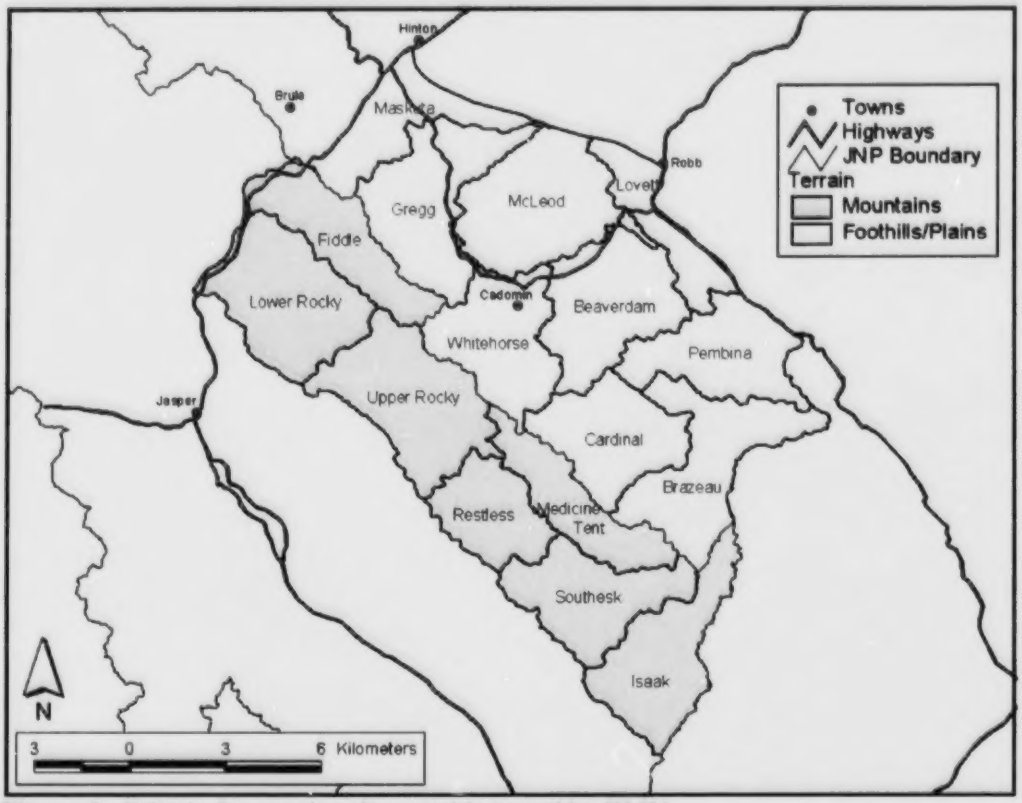


Figure 6. Criteria for creating the variable "mtn" by BMU

7.2.2 Results

Overall performance

In general, the Televilt collars had a better design and were easier to fit on the bear than ATS collars. In addition, the Televilt collars were more in keeping with the shape and weight of the traditional VHF collar. Conversely, the ATS collars were heavier and their overall shape and inflexibility made fitting of these collars difficult.

The Televilt collars also performed better than ATS on the basis of electronic/mechanical reliability. Only one of the 10 Televilt collars malfunctioned compared to 8 of the ATS collars. The one Televilt collar began prematurely transmitting on low battery mode. In

this state the collar attempted uploads but the VHF beacon never shut down so uploads were of a very poor quality and no data was recovered. This collar has not yet been retrieved.

The primary problem with the ATS collars was their vulnerability to flexing. The flexing and pulling of the collar by the bear broke the waterproof seal around the protective casing, enabling water to enter which in turn caused a short circuit in the electronics. In other instances, bears were able to pull the "releasing pin" out. Some bears were also able to slip out of the collar because of a poor fitting, which was primarily a function of awkward collar design. See Table 8 for a complete synopsis of the problems associated with ATS collars.

Table 8. Synopsis of ATS collar performance.

BearId	Sex	Collar type	Recovered	Date animal collared	Date collar recovered	Status
G003	F	ATS	yes	09/05/99	01/10/99	on Oct 1/99 collar was known to be in low battery mode; successfully triggered to remotely drop-off
G007	F	ATS	yes	19/05/99	28/10/99	collar on bear but failed to respond to remote transmitter because collar release mechanism had been damaged; collar no longer emitted a VHF pulse. Captured bear to retrieve the collar. The engineer was unable to the retrieve data because of electronic failure.
G009	F	ATS	yes	20/05/99	04/09/99	this collar was found by a hunter in a creek on Sept 4/99 and was returned to us on Oct 21/99; the collar no longer emitted a VHF signal and the drop-off mechanism was damaged. The engineer was unable to retrieve data from the collar because of the electronic failure.
G010	F	ATS	yes	25/05/99	30/09/99	on Sept 30 collar was known to be on mortality mode; the drop-off "pin" had been pulled out by the bear.
G011	F	ATS	no	05/05/99	na	found bear but collar not on bear; location of the collar unknown
G012	F	ATS	yes	26/05/99	02/06/99	on June 2/99 the collar was known to be in mortality mode; drop-off mechanism had been damaged
G014	M	ATS	no	06/06/99	na	found bear but collar not on bear; location of the collar unknown; suspected collar failure.
G017	M	ATS	yes	28/05/99	12/06/99	on June 12/99 the collar was on mortality mode; the collar was intact it but the bear slipped the collar over his head. An electronic malfunction resulted in the collar re-initializing frequently.
G021	M	ATS	no	20/06/99	na	location of bear and collar still unknown; suspected collar failure.

Location attempt success

When collar types were considered separately there was no significant difference in the location success rates between "mtn" types (ie inside or outside JNP). Televilt collars (X^2=0.248, p=0.618, df=1) (Table 9) and ATS collars (X^2=2.855, p=0.091, df=1) (Table 10) both performed as well in the park as they did outside. Although not significant, ATS collars had a higher success rate in both "mtn" types than Televilt.

When the proportion of unsuccessful location attempts was compared between collar types within the same "mtn" type, there was no difference between the performance of the collar types (X^2=0.208, p=0.648, df=1) in the area outside the mountains. However, there was a large difference in sample sizes (Table 11). In contrast, inside the mountains the proportion of successful location attempts made by ATS collars was significantly higher (X^2=23.79, p<0.001, df=1) than that of Televilt (Table 12). This is likely related to either the 12-channel receiver in the ATS collars or their ability to attempt a location acquisition 3 times within one measuring period.

Table 9. Televilt location success rate in and out of Jasper National Park

Televilt Location Attempts	Inside	Outside	n
% unsuccessful	33	34	469
% successful	67	66	917

Table 10. ATS location success rate in and out of Jasper National Park

ATS Location Attempts	Inside	Outside	n
% unsuccessful	19	31	124
% successful	81	69	506

Table 11. Comparison of location success rates between GPS collars outside of Jasper National Park

Outside Location Attempts	ATS	Televilt
% unsuccessful	31	34
% successful	69	66
n	36	1008

Table 12. Comparison of location success rates between GPS collars inside of Jasper National Park

Inside Location Attempts	ATS	Televilt
% unsuccessful	19	33
% successful	81	67
n	594	378

When all ATS and Televilt collar location attempts while on bears were considered regardless of "mtn" type, ATS collars appears to have a higher success rate. While on bears, no ATS collar had any days where a complete day (6 attempts) was missed. This is in sharp contrast to several days missed with the Televilt collars. The daily success rate was calculated by day and collar types, not by individual bear. Consequently, an individual collar may have had a no-data day, but other collars of that type were successful on that day and contributed to a success rating greater than zero for that day. The Televilt collars on G008 and G013 did have days with a zero success rating. The initiation of missed whole data days seemed to coincide closely with the estimated collar drop off date in several instances.

DOP Values

Based on mean DOP values, ATS and Televilt collars performed the same in mountainous areas as they did in flatter areas. Mean DOP values were relatively consistent and there was no significant affect of either collar type or habitat ("mtn") type ($F=0.3$, $df=1$, $p=0.72$) on DOP. As might be expected, there was also no difference in the mean DOP values of Televilt collar and Televilt upload data ($t=1.71$, $df=2706$, $p=0.09$).

3D and 2D fixes.

Within a collar type, the frequency of 3D fixes in the mountains was not different from that on flatter terrain (ATS, $X^2=0.01$, $df=1$, $p=0.90$; Televilt, $X^2=3.5$, $df=1$, $p=0.06$). Over both "mtn" types, ATS collars produced a significantly larger proportion (67.5%) of 3D fixes than did the Televilt units (40.7%; $X^2=259.15$, $df=1$, $p<0.001$). The mean DOP value of 3D fixes did not differ significantly from 2D fixes. Generally, DOP values for 3D fixes (mean=3.74 ± 0.09, 95%CI) were more tightly clustered around the mean than 2D fixes (mean=3.78 ± 0.18, 95%CI).

7.3 Home Range and Movements

7.3.1 Methods

(a) Home Ranges

Both the MCP and kernel home ranges were calculated using the Animal Movement Extension (Hooge and Eichenlaub 1997) for ARCVIEW GIS (ERSI Inc.). 100% MCPs for individual bears were calculated for pre-berry (den emergence to July 31), post-berry (Aug 1 to denning) and both seasons combined (i.e. annual home range). It should be noted that only bears with locations in the two seasons were used to calculate the annual home ranges. T-tests were used to test for differences between sex and season. Results were considered significant at $p=0.05$. Statistical analyses were performed with SPSS (Standard Version 9.0.0).

In addition, fixed kernel home ranges were also calculated for each bear. To avoid auto-correlation, the kernel home ranges were calculated using data sets, which were randomly sub-sampled to include only one location per day. 95%, 75%, 50%, and 25% of the estimated utilization distribution were used and the least square cross validation (LSCV)

method was used to select the bandwidth. Bears with less than 60 locations were not included and both seasons were combined in the kernel analysis.

(b)Rates of Movement

Data was obtained from 13 bears including 5 adult and 2 sub-adult females as well as 6 adult males. Data was sub-sampled to exclude locations collected after collar drop-off date. In cases where exact date of drop-off was not known it was estimated and was based on major declines in mean animal movement distance. In most instances our estimate was conservative. Furthermore, locations that showed unusually large movement distance (>90,000 km) within the given time frame were also removed from the data sample. These latter points comprised a very small proportion of the over all sample size.

To obtain movement rates, data was sorted sequentially by date and time and then a straight-line distance was calculated between consecutive UTMs. To obtain daily movement rates, the total number of locations were first sub-sampled such that 1 location/day was randomly selected. Daily movement was calculated by dividing the distance between consecutive locations by the number of days between points. Hourly movement was calculated by dividing the distance between consecutive locations by the hours between each point. Locations were also categorised into day and night based on the sunrise/sunset schedule for our study area. Locations ½ hr after sunset were classified as night while locations ½ hr after sunrise were classified as day. Both hourly and daily movement rates data were analyzed by individual bear, sex, and season. T-tests were used to test for differences between sex and season. All statistical analyses were calculated using SPSS.

(c)Road Crossings

The road layer used was derived from a combination of the Provincial roads database and Weldwood's FMA roads (1996). However, this layer only covers their FMA and does not include any new roads since 1996. Siesmic lines were not considered in this analysis. Roads were classified into the following categories: 1- Permanent, designed speed 90km/hr, and maximum road surface of 10m; 2- Permanent, designed speed 80km/hr, and maximum road surface of 10m; 3- Permanent, designed speed 60km/hr, and maximum road surface of 8m; 4 – Permanent/Temporary, speed na, and max road surface of 5.5m; 5 – Temporary, speed na, and max road surface of 6m; unknown – unclassified road. Any location falling outside the FMA boundary did not register road crossings, even if some may have existed.

For each bear, the path coverage was overlaid onto the data layer with FMA roads to create intersections. At each intersection, the two point locations at each end of the path were extracted. One was the 'from' location, the other 'to' location. Joining consecutive locations for each bear with a straight-line created the path coverage. Since the exact time of the crossing is not known the period of the 'from' and 'to' locations was used to determine if it occurred during the day or night. If the 'from' and 'to' locations were either both consecutive day locations or consecutive night locations then the crossing

event would be classified as a day or night crossing, respectively. Road crossings were analyzed by individual, sex and time of day.

7.3.2 Results

(a) Home Ranges

Table 13 shows the 100% MCPs calculated for each bear. When considering annual, pre-berry and post-berry seasons the mean home range size for females was 513.47 km^2 (SE=50.10 km^2; n=5), 669.65 km^2 (SE=253.10 km^2; n=7), and 170.40 km^2 (SE=76.0 km^2; n=5), respectively. G013, was caught close to the border on the east side of the study area and had a much larger home range than the other females (Table 13).

For male bears, the mean home range size for both seasons combined, pre-berry and post-berry seasons was 1007.60 km^2 (SE=310.15 km^2; n=4), 818.07 km^2 (SE=227.74 km^2; n=6), and 378.16 km^2 (SE=150.21 km^2; n=4), respectively. Although male home ranges tended to be larger than females, and pre-berry seasonal home ranges tended to be larger than post-berry, the results were not significant ($p>0.05$).

Table 13. 100% MCP (km^2) of collared grizzly bears.

		Both Seasons		Pre-Berry		Post-Berry	
Sex	BearId	Area	n	Area	n	Area	n
F	G002	565.33	371	347.66	174	469.87	197
	G003	383.26	619	333.24	391	221.21	228
	G004	459.66	800	388.93	406	224.04	394
	G010	482.26	553	396.04	333	332.43	220
	G012	101.65	29	101.65	29		
	G013	2049.54	218	2049.54	218		
	G020	676.85	554	228.51	110	616.87	444
M	G001	496.83	312	496.83	312		
	G005	1297.82	717	1280.41	384	735.99	333
	G006	992.69	493	977.6	334	185.82	159
	G008	1588.25	397	588.25	305	509.89	92
	G016	151.63	408	129.18	83	80.92	325
	G017	436.15	83	436.15	83		

It is clear in that the Jasper National Park boundary is permeable to bear movement (Figure 7). Nine of the 13 bears had locations both inside and outside the park. Not surprising, the current study area boundary is also permeable to bear movement, with 5 bears moving outside its limits. Two females moved eastward outside of the area, 1 male

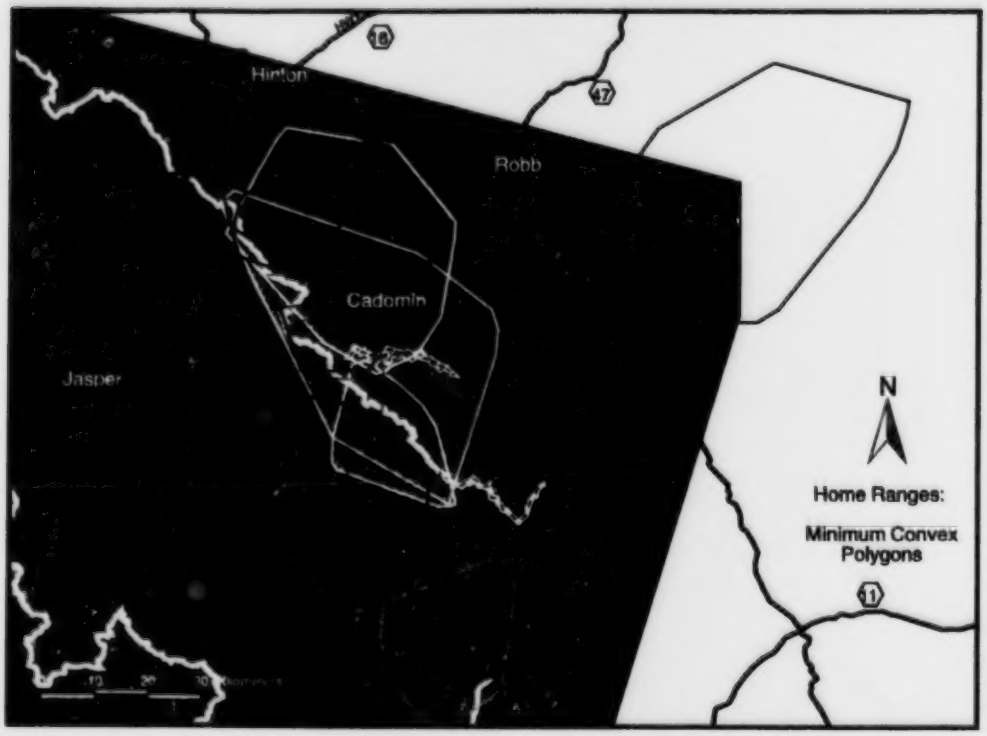


Figure 7. 100% Minimum convex polygons of collared grizzly bears

Table 14. Kernel home ranges (km^2) of collared grizzly bears.

Sex	BearId	n	Percentage of Utilization Distribution				Total
			95	75	50	25	
F	G002	94	442.08	123.83	38.25	10.92	615.07
	G003	131	270.47	84.17	34.60	11.68	400.92
	G004	163	181.12	40.48	14.60	5.10	241.29
	G010	100	389.60	77.88	21.84	7.81	497.13
	G013	60	1432.81	517.88	210.19	51.69	2212.57
	G020	154	314.75	114.12	42.78	12.11	483.76
M	G001	61	359.14	97.85	41.31	13.26	511.57
	G005	102	523.71	87.37	37.78	16.40	665.25
	G006	112	614.21	147.75	41.72	16.70	820.38
	G008	119	1047.03	312.62	73.24	23.72	1456.62
	G016	119	72.45	15.20	6.39	2.00	96.05

crossed highway 16 to the north, and 2 bears (1M; 1F) moved outside of the western border. Of these latter 2 bears, the female also moved southward outside the study area. Table 14 shows the kernel home ranges for each bear.

(b) Rates of Movement

Table 15 shows the daily movement rates for individuals. Female mean daily movement rates for both seasons combined, pre-berry and post berry seasons were 3862.35 m/day (SE=708.92 m; n=6), 3923.01 m/day (SE = 643.40 m; n=7) and 3238.28 m/day (SE= 240.27; n=5), respectively. Male mean daily movement rates were 4348.40 m/day (SE=788.10 m; n=4), 5483.60 m/day (SE=1102.81m; n=6), 3267.68 m/day (SE=862.05 m; n=4), for combined seasons, pre-berry, and post-berry seasons respectively. Although male movement rates were greater than females, and pre-berry seasonal movement rates were greater than post-berry, the differences were not significant.

Table 16 shows the hourly movement rates for all bears. Female mean hourly movement rates for both seasons combined, pre-berry, and post berry seasons were 258.82 m/hr (SE= 39.29 m; n=6), 270.42 m/hr (SE=35.02 m; n=7), and 226.99 m/hr (SE=14.62 m; n=5) respectively. Male mean hourly movement rates for both seasons combined, pre-berry and post-berry seasons were 283.15 m/hr (SE=40.96 m; n=4), 385.49 m/hr (SE=94.60 m; n=6), and 217.72 m/hr (SE=48.78 m; n=4) respectively. Again differences between males and females, and season were not significant.

Table 17 shows daytime and nighttime rates of movement for individual bears. Both males and females had higher movement rates during the day than the night but these results were not significant. Females, on average, moved 298.77 m/hr (SE=45.77 m;

Table 15. Daily movement rates (m/day) of collared grizzly bears.

Sex	BearId	N	Season	Mean	Minimum	Maximum
F	G002	93	both	2656.73	26.93	13247.64
		45	pre	2318.00	26.93	12027.65
		48	post	2974.30	48.33	13247.64
	G003	130	both	3484.20	46.82	22460.20
		83	pre	3433.02	46.82	15694.03
		47	post	3574.57	60.03	22460.20
	G004	162	both	2725.86	19.00	12343.22
		82	pre	3031.26	19.00	12343.22
		80	post	2412.82	37.64	11018.55
	G010	99	both	3318.35	90.45	15727.59
		67	pre	3149.04	90.45	10703.31
		32	post	3672.85	305.49	15727.59
	G012	6	both	3874.99	54.45	10496.44
		6	pre	3874.99	54.45	10496.44
	G013	59	both	7306.28	60.27	28118.70
		57	pre	7547.89	60.27	28118.70
		2	post	420.43	93.01	747.85
	G020	153	both	3682.60	31.51	14620.07
		35	pre	4106.87	55.68	14620.07
		118	post	3556.76	31.51	13150.62
M	G001	60	both	2478.07	9.43	28221.69
		60	pre	2478.07	9.43	28221.69
	G005	101	both	5794.11	28.30	25214.21
		81	pre	5816.73	28.30	25214.21
		20	post	5702.50	45.79	17012.03
	G006	111	both	4410.49	34.71	16394.84
		81	pre	5119.44	85.15	16394.84
		30	post	2496.33	34.71	8410.53
	G008	118	both	5047.20	21.30	33429.13
		77	pre	6054.49	21.30	33429.13
		41	post	3155.46	32.76	13371.98
	G016	118	both	2141.81	35.40	9562.25
		32	pre	3263.67	69.72	7777.13
		86	post	1724.37	35.40	9562.25
	G017	10	both	10169.17	233.47	28444.09
		10	pre	10169.17	233.47	28444.09

Table 16. Hourly movement rates (m/hr) of collared grizzly bears.

Sex	BearId	N	Season	Mean	Minimum	Maximum
F	G002	369	both	228.38	2.20	2972.76
		173	pre	217.82	2.20	2972.76
		197	post	237.70	3.26	1558.65
	G003	618	both	230.41	0.14	2298.56
		390	pre	229.17	0.14	1602.20
		228	post	232.54	2.94	2298.56
	G004	793	both	188.24	0.99	1339.79
		405	pre	197.66	3.11	1241.17
		388	post	178.40	0.99	1339.79
	G010	482	both	221.20	3.26	1601.38
		332	pre	199.99	3.26	1388.17
		150	post	268.12	4.27	1601.38
	G012	28	both	299.56	5.76	1232.42
		28	both	299.56	5.76	1232.42
	G013	193	both	452.41	1.97	2690.56
		190	pre	459.03	1.97	2690.56
		3	post	33.14	6.75	56.72
	G020	553	both	232.29	0.00	1559.09
		109	pre	289.68	5.75	1363.66
		444	post	218.20	0.00	1559.09
M	G001	248	both	170.78	1.53	2619.29
		248	pre	170.78	1.53	2619.29
	G005	481	both	362.53	1.19	2459.66
		383	pre	365.23	1.19	2459.66
		98	post	351.97	2.00	2050.94
	G006	425	both	280.13	0.80	1796.48
		333	pre	317.04	1.25	1796.48
		92	post	146.56	0.80	955.76
	G008	393	both	318.82	0.99	2738.60
		304	pre	345.44	0.99	2738.60
		89	post	227.87	3.06	1276.73
	G016	405	both	171.12	0.00	3077.21
		82	pre	277.32	5.12	3077.21
		324	post	144.57	0.00	1633.08
	G017	65	both	837.10	0.56	2910.91
		65	pre	837.10	0.56	2910.91

Table 17. Day- and nighttime movement rates (m/hr) of collared grizzly bears.

Sex	BearId	N	Period	Mean	Minimum	Maximum
F	G002	163	day	254.30	2.78	2809.58
		51	night	101.77	3.02	1074.73
	G003	246	day	191.80	3.78	1547.60
		113	night	290.95	11.30	1583.56
	G004	348	day	231.40	1.20	1273.30
		138	night	53.86	0.93	529.56
	G010	196	day	204.85	3.36	1601.38
		89	night	313.02	13.28	1538.95
	G012	15	day	342.01	9.03	1096.10
	G013	71	day	540.85	10.30	2690.55
		20	night	189.67	1.98	727.03
	G020	168	day	326.16	3.35	1522.66
		114	night	62.79	0.00	397.70
M	G001	120	day	178.24	2.54	2619.30
		26	night	74.34	2.40	315.90
	G005	224	day	302.65	2.00	2050.93
		63	night	269.68	1.20	1961.35
	G006	177	day	277.49	3.58	1642.08
		47	night	118.85	1.20	1111.50
	G008	174	day	385.35	0.99	2724.90
		29	night	78.01	2.30	385.48
	G016	146	day	195.54	0.00	1633.08
		60	night	73.17	7.50	457.71
	G017	6	night	648.80	35.88	1871.88

n=7) during the day and 168.68 m/hr (SE=46.58 m; n=6) during the night. Similarly, males moved an average of 267.85 m/hr (SE=37.66 m; n=5) during the day and 210.48 m/hr (SE=92.91 m; n=6) in the night. There were no significant differences between males and females.

(c) Road Crossings

9 grizzly bears, including 4 females and 5 males were known to have crossed provincial and Weldwood FMA classified roads (Table 18). The remaining 4 bears for which road crossings were not recorded had home ranges either primarily inside JNP or outside of the FMA. Females and males made a total of 322 and 299 crosses, respectively. However, 94% of the female crossings were made by G020 while 66% of the male crossings were made by G005.

Of the 4 females only G012 and G020 had relatively high road densities in their home ranges, with a total of 0.38 km/km^2 and 0.47 km/km^2, respectively (Table 18). It appears, however, that these two females responded very differently with respects to road crossing. Both females crossed road class 3 more frequently (total = 143 times) than any other road class, however, G020 made 138 crossings while G012 made only 5 even

Table 18. Total number of bear crossings of Provincial and Weldwood FMA road classes; c=no. of crossing, d= total road density (km/km^2).

Sex	BearId	Road Class												Total	
		1		2		3		4		5		unknown			
		c	d	c	d	c	d	c	d	c	d	c	d	c	d
F	3	0	0.00	0	0.00	4	0.01	0	0.00	0	0.00	0	0.00	4	0.01
	4	0	0.01	4	0.02	2	0.02	0	0.00	0	0.00	1	0.02	7	0.08
	12	2	0.16	0	0.00	5	0.23	0	0.00	0	0.00	0	0.00	7	0.38
	20	77	0.06	66	0.05	138	0.24	10	0.05	12	0.07	0	0.00	303	0.47
	Total F	**79**	**0.23**	**70**	**0.08**	**149**	**0.49**	**10**	**0.05**	**12**	**0.07**	**1**	**0.02**	**322**	**0.94**
M	5	50	0.05	13	0.03	88	0.17	15	0.01	27	0.06	4	0.02	197	0.34
	6	0	0.00	0	0.00	2	0.001	0	0.00	0	0.00	0	0.00	2	0.001
	8	8	0.02	4	0.02	22	0.04	3	0.00	19	0.02	0	0.01	56	0.11
	16	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.002	1	0.002
	17	5	0.06	0	0.01	27	0.21	2	0.02	5	0.09	4	0.02	43	0.41
	Total M	**63**	**0.13**	**17**	**0.06**	**139**	**0.42**	**20**	**0.04**	**51**	**0.16**	**9**	**0.05**	**299**	**0.85**
	Grand Total	142	0.35	87	0.13	288	0.91	30	0.09	63	0.24	10	0.07	621	1.79

though the density of this road class was similar in each home range. Also G012 made much fewer crosses of road class 1 than G020 even though the density of this road class was greater in G012's home range. These observations should be interpreted with caution because of the large differences in sample sizes between these two bears

Of the 5 males only G005, G008 and G017 had relatively high road densities in their home ranges, with a total of 0.34 km/km^2, 0.11 km/km^2, and 0.41 km/km^2, respectively. All three bears crossed road class 3 more frequently than any other road class, however, this road class was also most common in each of the three home ranges (Table 18). The majority of road class 1 crossings (79%) were made by G005 even though the density of this road class was similar among G005's, G008's and G017's home ranges.

Based on preliminary results it appears that the majority of road crossings occurred during the daytime (Table 19 and Table 20). For females a total of 108 daytime and 19 nighttime crossings were recorded. Similarly, a total of 203 daytime and 30 nighttime crossings were recorded for males.

7.4 Habitat

7.4.1 Introduction

Grizzly bears require forested landscapes for a variety of reasons including forage, security areas, and denning sites. We are fortunate to have a variety of GIS data sets which we are utilizing to investigate the relationships between grizzly bear movements/locations and habitats/ecological conditions. These relationships are complex and will require many years of data before meaningful conclusions may be warranted. However, as a first step to look at bear habitat use in relation to habitat types we have provided a general overview of how our bear location data for 1999 was distributed within the various habitat quality values and forest stand ages within the study area.

It is important to recognize that additional analysis is ongoing utilizing remote sensing data, eco-classification data, and a variety of other vegetation data sets supplied to us by our program partners who are active on the study area landbase. Further and more detailed analysis of these data is ongoing and requires additional years of data collection.

7.4.2 Methods

(a) Habitat Quality Selection

The habitat layer used was a combination of a habitat layer created by Jasper National Park (JNP) and a habitat layer created for the Cheviot Mine Environmental Assessment. JNP has a different habitat layer for each month between April and October on a 5-point (0.0 to 5.0) and is significant to one digit. The coverage is based on an ecosite classification reported in Kanas and Raines (1995). The Cheviot habitat layer is on a 5-point scale (1 to 5) where 1 is very poor habitat and 5 is very good. There is a pre-berry and post-berry habitat layer for Cheviot. Since the JNP habitat layer is significant to one digit, the following breakdown was done to be on the same scale as the Cheviot data:

1 == 0.0 - 1.0 (both 0.0 and 1.0 are inclusive)
2 == 1.1 - 2.0

Table 19. Total number of daytime bear crossings of Provincial and Weldwood FMA road classes; c=no. of crossing, d= total road density (km/km²).

Sex	BearId	Road Class 1		2		3		4		5		unknown		Total	
		c	d	c	d	c	d	c	d	c	d	c	d	c	d
F	3	0	0.00	0	0.00	2	0.01	0	0.00	0	0.00	0	0.00	2	0.01
	4	0	0.01	2	0.02	0	0.02	0	0.00	0	0.00	0	0.02	2	0.08
	12	0	0.16	0	0.00	2	0.23	0	0.00	0	0.00	0	0.00	2	0.38
	20	22	0.06	17	0.05	48	0.24	7	0.05	7	0.07	0	0.00	101	0.47
	Total F	**22**	**0.23**	**19**	**0.08**	**52**	**0.49**	**7**	**0.05**	**7**	**0.07**	**0**	**0.02**	**108**	**0.94**
M	5	12	0.05	3	0.03	31	0.17	6	0.01	6	0.06	0	0.02	58	0.34
	8	4	0.02	2	0.02	5	0.04	0	0.00	7	0.02	0	0.01	18	0.11
	16	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.002	1	0.002
	17	1	0.06	0	0.01	15	0.21	2	0.02	0	0.09	0	0.02	18	0.41
	Total M	**39**	**0.13**	**24**	**0.06**	**103**	**0.42**	**15**	**0.04**	**20**	**0.16**	**1**	**0.05**	**203**	**0.85**
	Grand Total	61	0.36	43	0.14	155	0.91	22	0.09	27	0.23	1	0.07	309	1.79

Table 20. Total number of nighttime bear crossings of Provincial and Weldwood FMA road classes; c=no. of crossing, d= total road density (km/km²).

Sex	BearId	Road Class 1		2		3		4		5		unknown		Total	
		c	d	c	d	c	d	c	d	c	d	c	d	c	d
F	20	7	0.06	3	0.05	9	0.24	0	0.05	0	0.07	0	0.00	19	0.47
	Total F	**7**	**0.06**	**3**	**0.05**	**9**	**0.24**	**0**	**0.05**	**0**	**0.07**	**0**	**0.00**	**19**	**0.47**
M	5	6	0.05	0	0.03	8	0.17	4	0.01	5	0.06	0	0.02	23	0.34
	8	0	0.02	0	0.02	1	0.04	0	0.00	3	0.02	0	0.01	4	0.11
	17	0	0.06	0	0.01	2	0.21	0	0.02	0	0.09	0	0.02	2	0.41
	Total M	**6**	**0.13**	**0**	**0.06**	**11**	**0.42**	**4**	**0.04**	**8**	**0.16**	**0**	**0.05**	**30**	**0.85**
	Grand Total	13	0.19	3	0.11	20	0.66	4	0.09	8	0.23	0	0.05	49	1.32

3 == 2.1 - 3.0
4 == 3.1 - 4.0
5 == 4.1 - 5.0

For this combined layer, the JNP May habitat layer and the pre-berry habitat layer for Cheviot were used. Where both layers overlapped, the JNP habitat layer took precedence. A hundred meters buffered each location (i.e. the average error associated with the GPS collars) and the habitat value, which comprised the highest proportion of this buffer, was used in the analysis. To avoid auto-correlation, habitat selection was calculated using data sets, which were randomly sub-sampled to include only one location per day. The data was analyzed in the following two ways: (1) pooled among individuals and (2) separately by individual bear. For pooled data the availability of each habitat quality value was determined for pre- and post-berry 100% MCP of all bears combined. At the level of the individual, the availability of each habitat quality value was determined for each bear's pre- and post-berry 100% MCP. Only bears with > 20 locations/season were used in this portion of the analysis. Differences in distribution for both levels of analysis were examined using Chi-square analysis, and preference was determined using Bonferonni confidence intervals as described by Neu et al. 1974. Significance of all tests was considered to be p=0.05.

(b) Forest Stand Age

For the current analysis we utilized the "Forest Stand Age Map" of the Foothills Model Forest Natural Disturbance Program. Full details on the methodologies employed in creating this 1997 map are available through the FMF office. This GIS map product provides stand age forest polygons for our study area. The age classes are roughly divided into; pre 1710, 1710-1810, and then in 20-year age class increments until 1997. The class of non-forested is defined as those areas of rock, snow/ice or marshes/fens/bogs or other lands where tree growth is limited or non-existent.

Our GPS bear location data set was utilized to extract all data points by individual bears for 1999 and then the MCP home range method was used to define individual home ranges. Each bear's home range was then classified according to the percentage of the various forest stand age classes within it. We then overlayed the individual bears locations data points and calculated the percentage of points falling into each of the stand age categories.

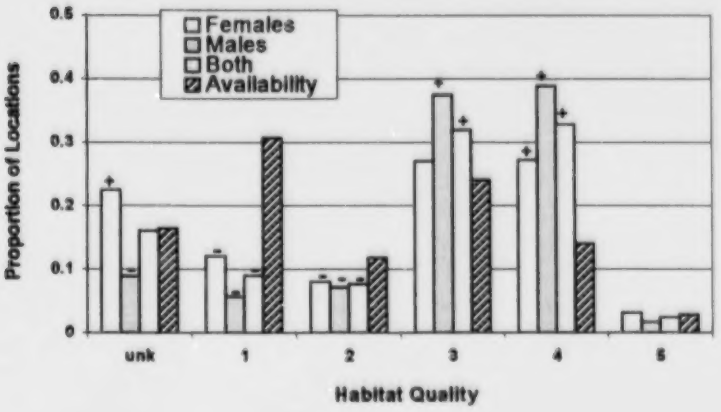
7.4.3 Results

(a) Habitat Quality Selection

For pooled data, the distribution of telemetry locations during the pre-berry season for females (X^2=105, p≤0.05, df=5), males (X^2=268, p≤0.05, df=5) and both sexes (X^2=323, p≤0.05, df=5) combined was not consistent with the availability of habitat types. This tends to support the concept of habitat selection. During pre-berry season, both males and females avoided habitat types 1 and 2, but selected habitat type 4 (Figure 8). Only males selected habitat type 3. Both sexes used habitat type 5, in equal proportion to its availability.

During the post-berry season, females (X^2=184, p≤0.05, df=5), males (X^2=262, p≤0.05, df=5) and both sexes combined (X^2=309, p≤0.05, df=5) use of the habitat types differed from their availability. Figure 9 indicates that both sexes avoided habitat types 1 and 2. In addition, while males tended to use habitat type 4 more than expected the females tended to avoid it. Among females, habitat type 5 was used more than it's availability but the results were not significant. Conversely, males used this habitat type less than expected.

Figure 8. Use and avilability of pre-berry habitat quality by grizzly bears in 1999; +/- indicates results are significant.



Although there was not enough data to statistically examine habitat selection by individual bear, Table 21 and Table 22 indicate some individual variation in use of habitat types among bears during pre- and post-berry seasons.

(b) Forest Stand Age

This analysis of use versus availability by stand age classes is presented for 13 separate bears in Figures 10-22.

Figure 9. Use and availability of post-berry habitat quality by grizzly bears in 1999; +/- indicates results are significant.

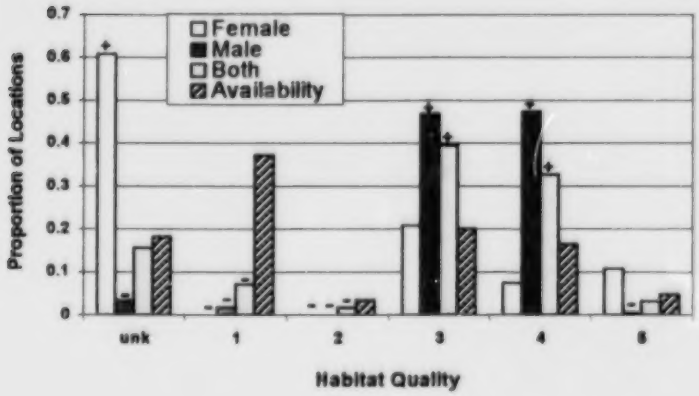


Table 21. Use and availability of pre-berry habitat by individual bear in 1999; u=use and a=availability.

Sex	BearId	Habitat Quality Values											
		1		2		3		4		5		unknown	
		u	a	u	a	u	a	u	a	u	a	u	a
F	2	0.13	0.51	0.11	0.07	0.07	0.16	0.59	0.20	0.02	0.01	0.09	0.06
	3	0.19	0.52	0.01	0.03	0.40	0.25	0.29	0.11	0.11	0.08	0.00	0.00
	4	0.22	0.26	0.06	0.12	0.42	0.36	0.29	0.21	0.01	0.05	0.00	0.00
	10	0.09	0.50	0.21	0.09	0.31	0.22	0.40	0.17	0.00	0.01	0.00	0.00
	12	0.00	0.00	0.43	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.97
	13	0.00	0.00	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.97	0.98
	20	0.00	0.00	0.06	0.10	0.25	0.13	0.06	0.06	0.03	0.02	0.61	0.68
M	1	0.21	0.51	0.03	0.08	0.15	0.22	0.61	0.18	0.00	0.01	0.00	0.00
	5	0.00	0.07	0.05	0.12	0.44	0.22	0.23	0.14	0.01	0.03	0.27	0.42
	6	0.07	0.37	0.07	0.12	0.30	0.27	0.51	0.21	0.04	0.04	0.00	0.00
	8	0.01	0.22	0.12	0.13	0.49	0.36	0.29	0.17	0.01	0.05	0.08	0.07
	16	0.00	0.31	0.00	0.02	0.64	0.32	0.33	0.30	0.03	0.06	0.00	0.00
	17	0.00	0.02	0.36	0.11	0.09	0.27	0.27	0.18	0.00	0.02	0.27	0.41

Table 22. Use and availability of post-berry habitat by individual bear in 1999; u=use and a=availability.

Sex	BearId	Habitat Quality Values											
		1		2		3		4		5		unknown	
		u	a	u	a	u	a	u	a	u	a	u	a
F	G002	0.33	0.66	0.06	0.06	0.52	0.13	0.06	0.09	0.02	0.06	0.00	0.00
	G003	0.26	0.56	0.02	0.03	0.45	0.18	0.26	0.19	0.02	0.03	0.00	0.00
	G004	0.04	0.44	0.03	0.04	0.35	0.29	0.59	0.22	0.00	0.02	0.00	0.00
	G010	0.06	0.60	0.09	0.04	0.53	0.12	0.31	0.23	0.00	0.02	0.00	0.00
	G020	0.00	0.00	0.00	0.03	0.21	0.04	0.08	0.03	0.11	0.003	0.00	0.00
M	G005	0.00	0.06	0.00	0.06	0.55	0.30	0.10	0.18	0.05	0.02	0.00	0.00
	G006	0.07	0.46	0.00	0.02	0.57	0.17	0.37	0.34	0.00	0.01	0.00	0.00
	G008	0.00	0.16	0.00	0.03	0.63	0.54	0.37	0.23	0.00	0.03	0.00	0.00
	G016	0.01	0.24	0.00	0.00	0.34	0.34	0.65	0.41	0.00	0.00	0.00	0.00

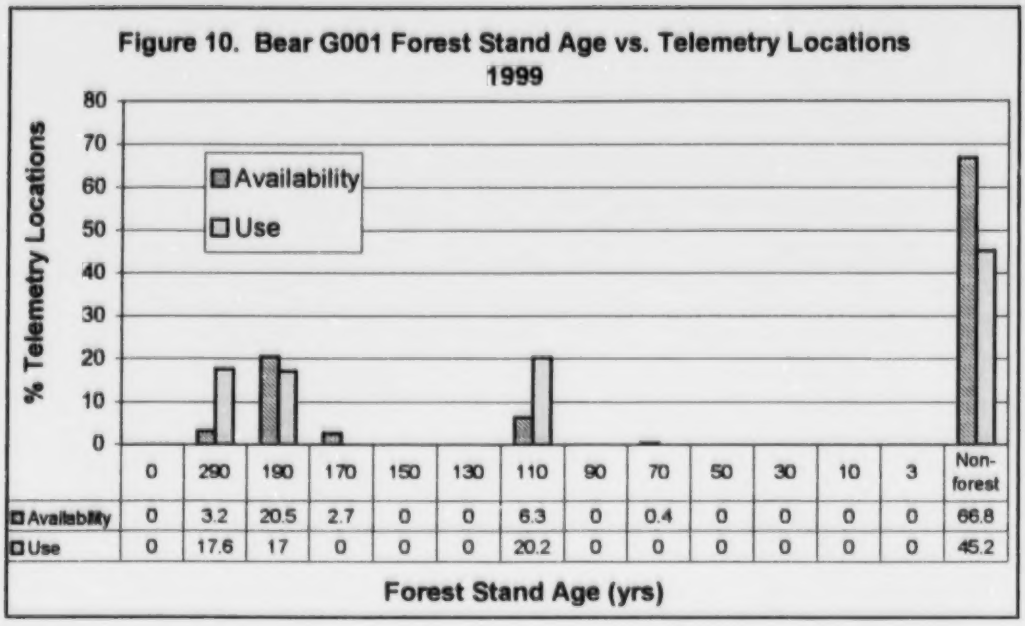


Figure 10. Bear G001 Forest Stand Age vs. Telemetry Locations
1999
% Telemetry Locations
80
70
60
50
40
30
20
10
0
Availability
Use
0 290 190 170 150 130 110 90 70 50 30 10 3 Non-forest
Availability 0 3.2 20.5 2.7 0 0 6.3 0 0.4 0 0 0 0 66.8
Use 0 17.6 17 0 0 0 20.2 0 0 0 0 0 0 45.2
Forest Stand Age (yrs)

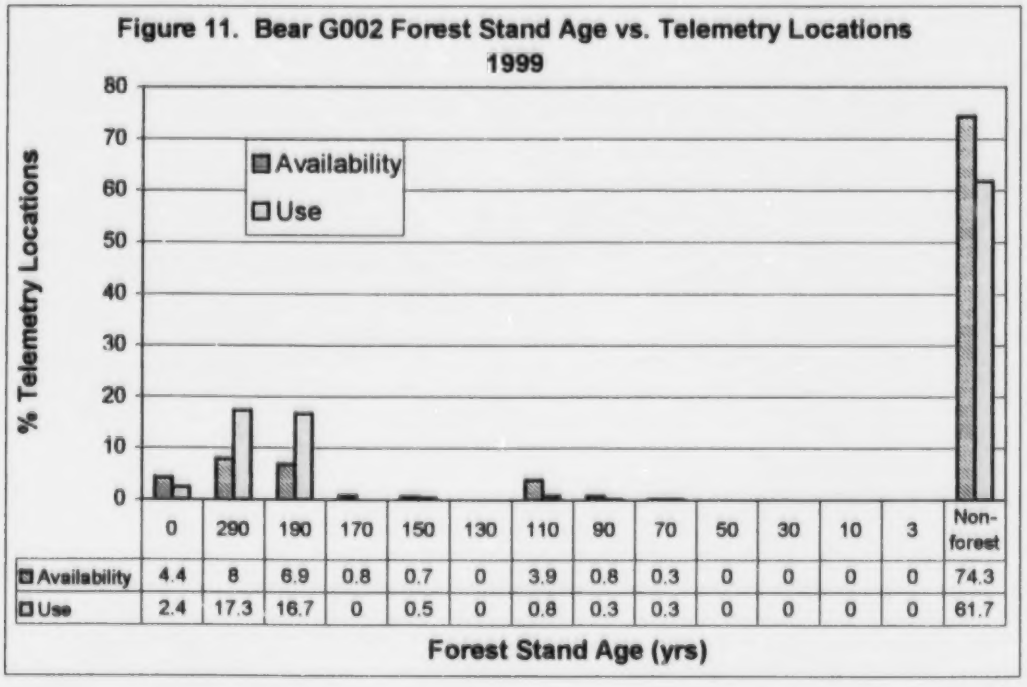
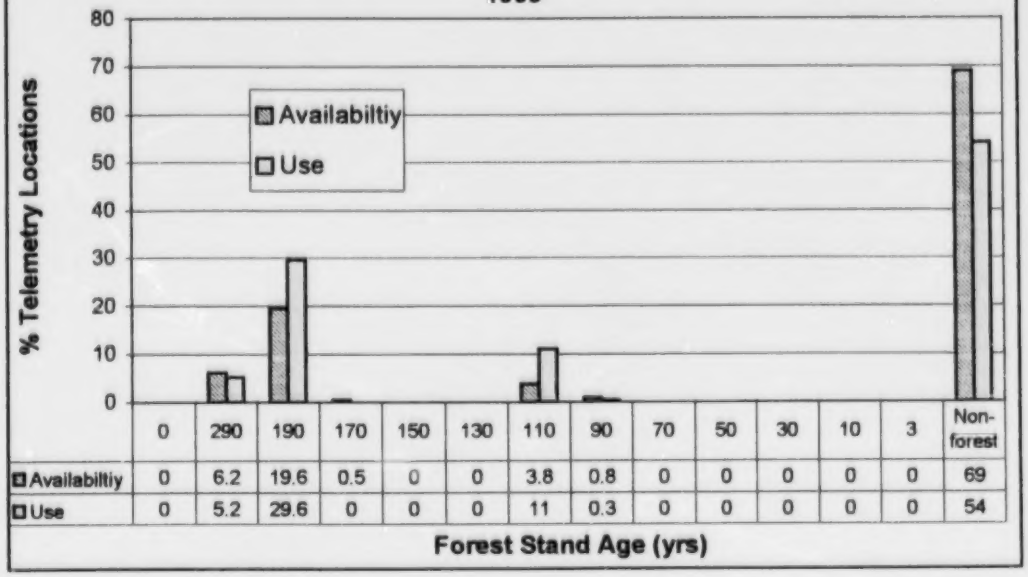


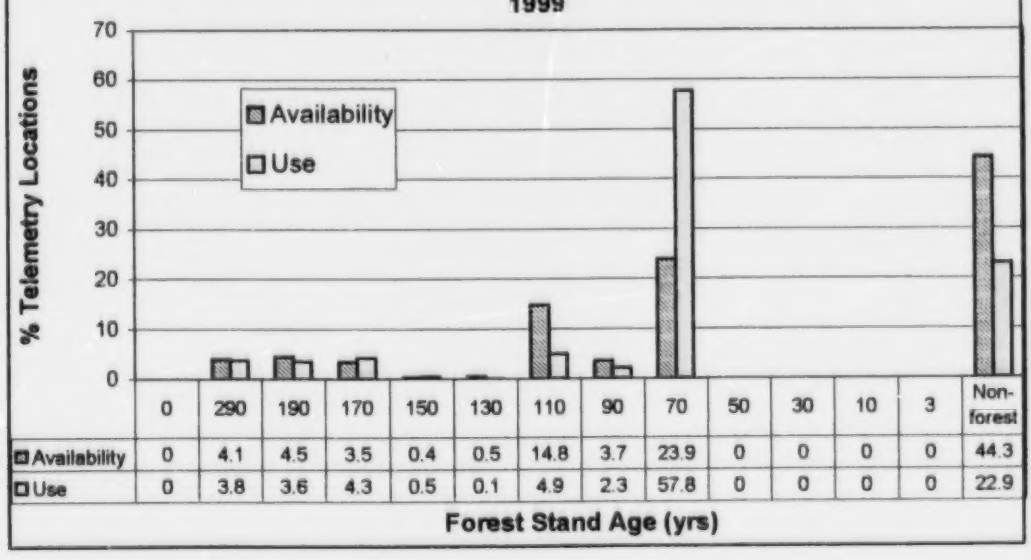
Figure 11. Bear G002 Forest Stand Age vs. Telemetry Locations
1999
% Telemetry Locations
80
70
60
50
40
30
20
10
0
Availability
Use
0 290 190 170 150 130 110 90 70 50 30 10 3 Non-forest
Availability 4.4 8 6.9 0.8 0.7 0 3.9 0.8 0.3 0 0 0 0 74.3
Use 2.4 17.3 16.7 0 0.5 0 0.8 0.3 0.3 0 0 0 0 61.7
Forest Stand Age (yrs)

Figure 12. Bear G003 Forest Stand Age vs. Telemetry Locations 1999



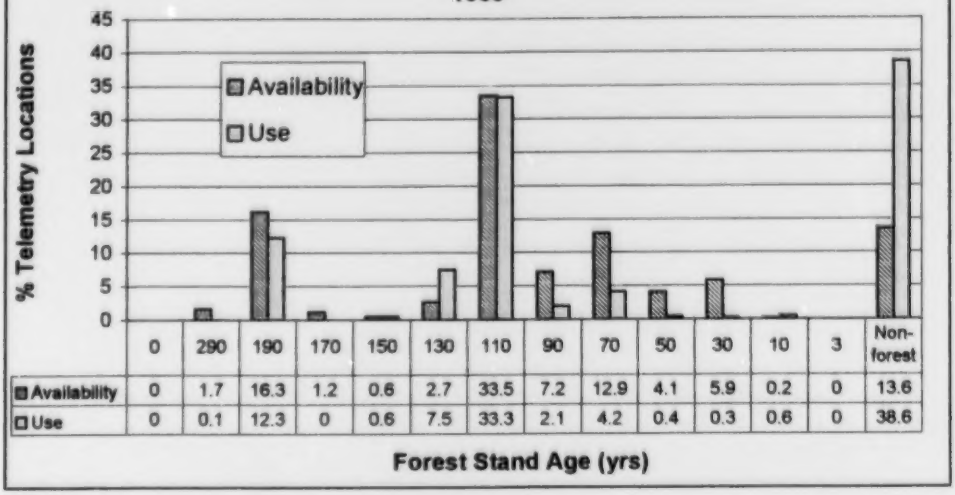
	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availabiltiy	0	6.2	19.6	0.5	0	0	3.8	0.8	0	0	0	0	0	69
Use	0	5.2	29.6	0	0	0	11	0.3	0	0	0	0	0	54

Figure 13. Bear G004 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	4.1	4.5	3.5	0.4	0.5	14.8	3.7	23.9	0	0	0	0	44.3
Use	0	3.8	3.6	4.3	0.5	0.1	4.9	2.3	57.8	0	0	0	0	22.9

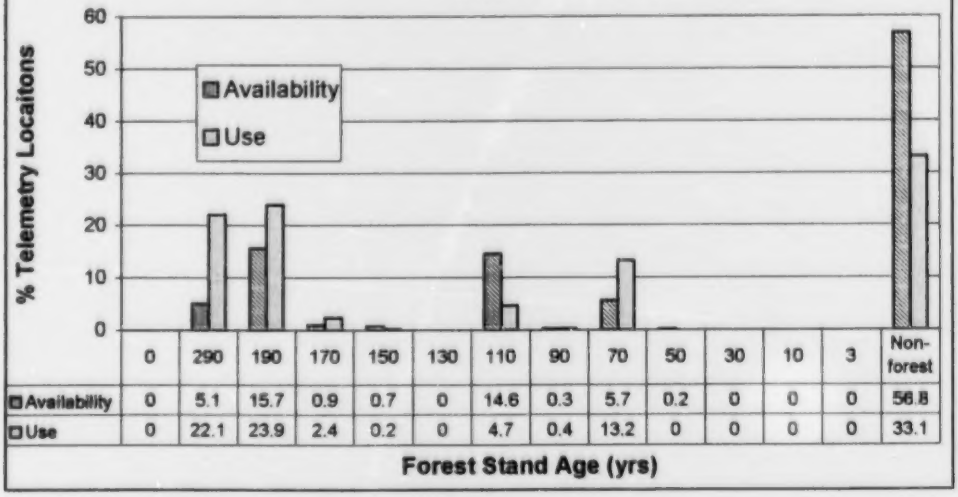
Figure 14. Bear G005 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	1.7	16.3	1.2	0.6	2.7	33.5	7.2	12.9	4.1	5.9	0.2	0	13.6
Use	0	0.1	12.3	0	0.6	7.5	33.3	2.1	4.2	0.4	0.3	0.6	0	38.6

Forest Stand Age (yrs)

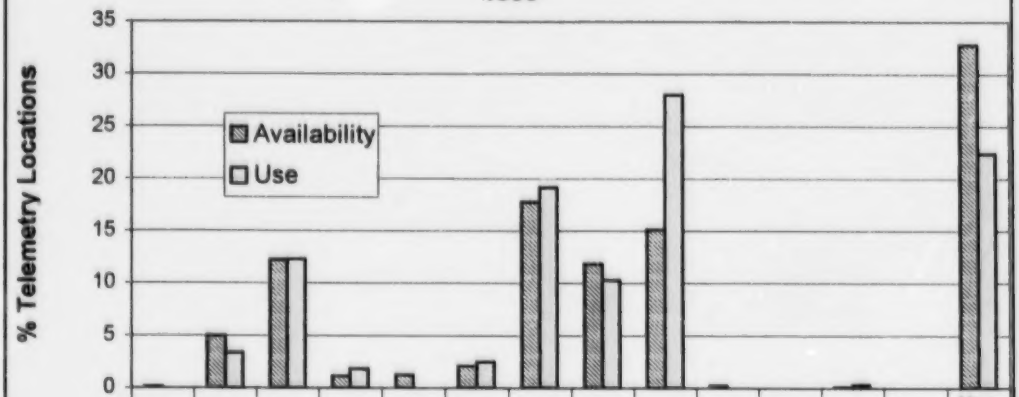
Figure 15. Bear G006 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	5.1	15.7	0.9	0.7	0	14.6	0.3	5.7	0.2	0	0	0	56.8
Use	0	22.1	23.9	2.4	0.2	0	4.7	0.4	13.2	0	0	0	0	33.1

Forest Stand Age (yrs)

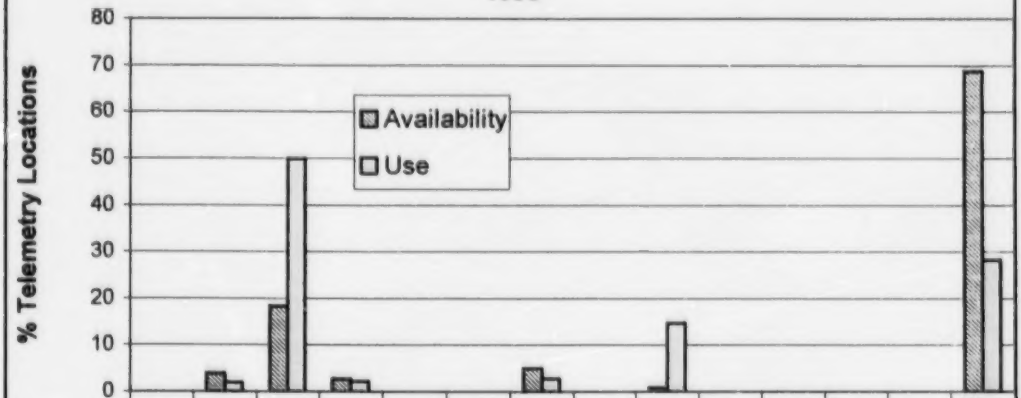
Figure 16. Bear G008 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0.1	5	12.2	1.1	1.2	2.1	17.8	11.9	15.1	0.2	0	0.1	0	32.8
Use	0	3.3	12.3	1.8	0	2.5	19.1	10.3	28	0	0	0.3	0	22.4

Forest Stand Age (yrs)

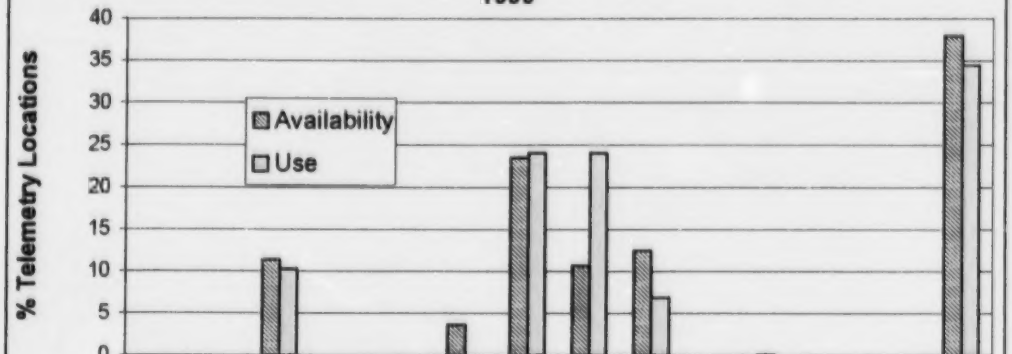
Figure 17. Bear G010 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	4	18.3	2.8	0	0	5.1	0	0.9	0	0	0	0	68.8
Use	0	2	49.9	2.2	0	0	2.9	0	14.8	0	0	0	0	28.2

Forest Stand Age (yrs)

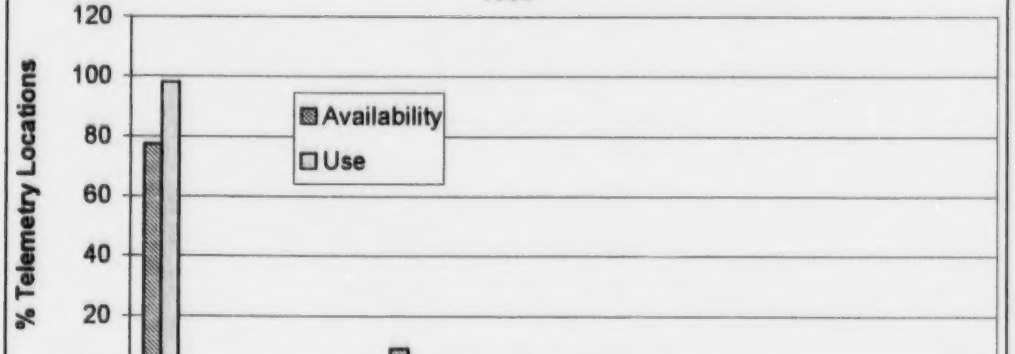
Figure 18. Bear G012 forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	0	11.4	0	0	3.7	23.5	10.7	12.5	0	0.1	0	0	38
Use	0	0	10.3	0	0	0	24.1	24.1	6.9	0	0	0	0	34.5

Forest Stand Age (yrs)

Figure 19. Bear G013 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	77.5	0	1.2	0	9.3	2.4	3.9	3.1	0.4	0.2	0	0	0	2.1
Use	98.2	0	0	0	1.4	0	0	0.5	0	0	0	0	0	0

Forest Stand Age (yrs)

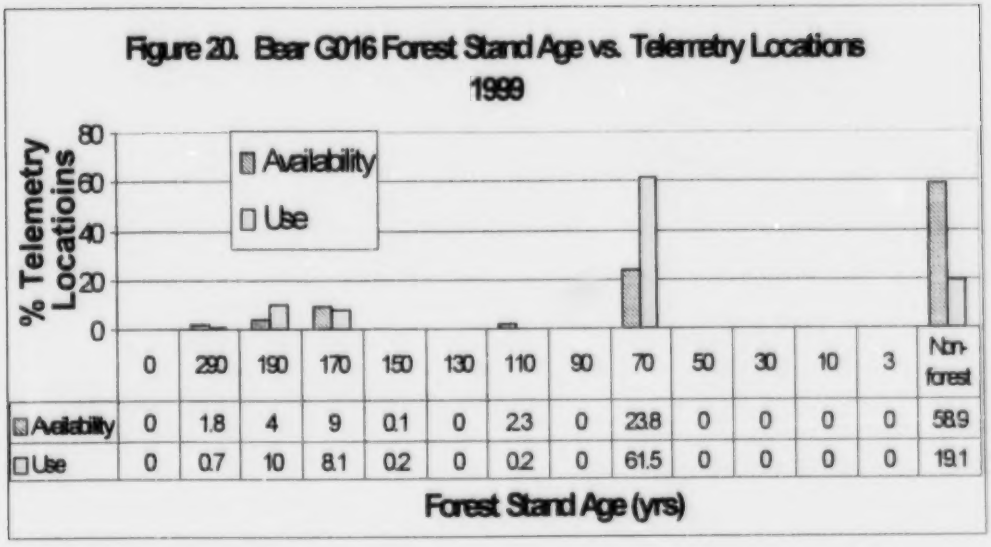


Figure 20. Bear G016 Forest Stand Age vs. Telemetry Locations 1999
% Telemetry Locatioins
80
60
40
20
0
Availability
Use
0 290 190 170 150 130 110 90 70 50 30 10 3 Non-forest
Availability 0 1.8 4 9 0.1 0 2.3 0 23.8 0 0 0 0 58.9
Use 0 0.7 10 8.1 0.2 0 0.2 0 61.5 0 0 0 0 19.1
Forest Stand Age (yrs)

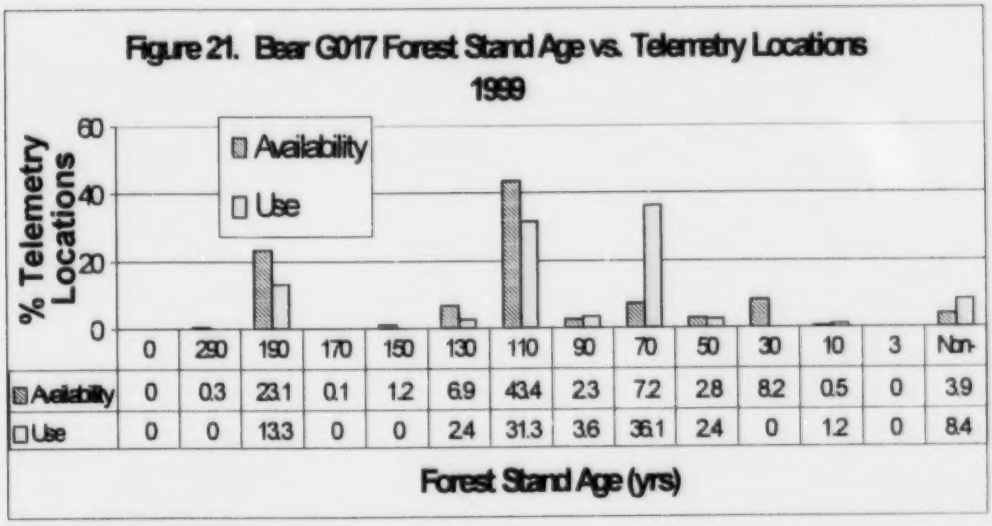
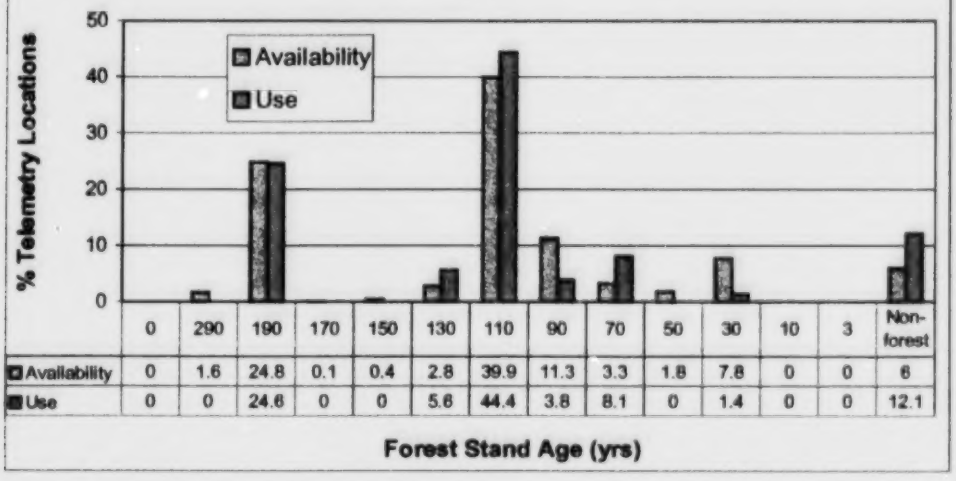


Figure 21. Bear G017 Forest Stand Age vs. Telemetry Locations 1999
% Telemetry Locations
60
40
20
0
Availability
Use
0 290 190 170 150 130 110 90 70 50 30 10 3 Non-
Availability 0 0.3 23.1 0.1 1.2 6.9 43.4 2.3 7.2 2.8 8.2 0.5 0 3.9
Use 0 0 13.3 0 0 2.4 31.3 3.6 36.1 2.4 0 1.2 0 8.4
Forest Stand Age (yrs)

Figure 22. Bear G020 Forest Stand Age vs. Telemetry Locations 1999



	0	290	190	170	150	130	110	90	70	50	30	10	3	Non-forest
Availability	0	1.6	24.8	0.1	0.4	2.8	39.9	11.3	3.3	1.8	7.8	0	0	6
Use	0	0	24.6	0	0	5.6	44.4	3.8	8.1	0	1.4	0	0	12.1

Forest Stand Age (yrs)

8.0 Status and Trends/DNA

Background

Large carnivores are and continue to be difficult to census. However monitoring population numbers of grizzly bears is important if managers are to be able to determine if conservation objectives are being met and to be able to objectively assess and predict cumulative impacts of human activities occurring within grizzly bear habitat. Recent advances in DNA fingerprinting have made it possible, with appropriate samples, to be able to identify individual bears in an area as well as to trace family lineages (Strobeck 1991, Craighead et al 1995, Mowat and Strobeck 1998, Paetkau et al 1998 and others). In addition, with appropriate sampling techniques and with adequate "captures" statistical techniques have evolved to provide estimates of population size within research study areas (Mowat et al 1998, Boulanger 1998). The reasons these techniques have been welcomed by wildlife biologist is that they are non-invasive and were originally thought to avoid some of the problems and cost with traditional mark-recapture techniques. Unfortunately as more field programs have used these techniques we have learned that they too have drawbacks and require careful consideration in study design.

One of the major challenges facing wildlife biologists and mangers who are responsible for grizzly bear management is the ability to determine population size, whether by bear management unit, watershed or geographical boundary. When one considers long term conservation efforts and sustainable management philosophies it seems realistic to look at techniques and methodologies that would allow managers to monitor population trends over time in a cost effective manner. The development of these techniques and approaches is a major goal of this program.

During the 1999 field program we initiated work to provide a minimum count of grizzly bears within the defined research study area. We utilized three separate DNA collection techniques (barbed wire hair snagging, rub pads and scat collection) to identify individual bears within the research study area. It was recognized that all of these techniques have biases and limitations, however they all provide DNA for the recognition of individuals.

Our program used a combination of these 3 techniques, within a comprehensive study design, to compare and contrast these methods and to come up with a minimum count of bears in the research study area. Our approach included:

1. The use of hanging baits and barbed wire to snag hair for DNA analysis
2. The use of stationary scented rub pads secured on trees to snag hair for DNA analysis
3. Collecting grizzly bear scats as one component of the field program and refining the laboratory procedures necessary for utilizing scat collection for DNA analysis enabling identification of individual grizzly bears.

(note: DNA samples were also collected from all bears captured during this program)

8.1 Hair Snaring - DNA Inventory 1999

Investigators: Garth Mowat, Kelly Stalker, Gordon Stenhouse, and Dr. Curtis Strobeck.

Note: The following analysis should be considered preliminary in nature since the complete 1999 DNA data set has not been finalized as of February 2000. Once completed and analyzed the complete DNA results will be appended as an addendum to this annual report.

8.1.1 Introduction

The estimation of grizzly bear abundance is difficult and most researchers have used intensive live capture and telemetry, within relatively small areas, to estimate grizzly bear population size (LeFranc et al. 1987, McLellan 1989, Nagy and Haroldson 1989, Mace and Waller 1997). More recently, workers have used remote removal of hair, combined with DNA microsatellite fingerprinting to identify individuals and estimate population size (Woods et al. 1999, Boulanger 1998a, Poole et al. 1999, Mowat and Strobeck 2000). In more open habitats biologists have used radio tagging to mark bears followed by aerial resighting surveys to estimate bears population size (Miller et al. 1999) These methods greatly reduce costs and allow workers to sample larger areas and follow study designs that meet the assumptions of several contemporary mark-recapture estimators. But, DNA mark-recapture studies that have estimated population size to date have utilised intensive trapping regimes and have been prohibitively expensive for broad application by bear managers (Woods et al. 1999, Poole et al. 1999, Mowat and Strobeck 2000).

These recent intensive hair capture efforts have captured 40-70% of the estimated population (Boulanger 1998a, Poole et al. 1999, Woods et al. 1999, Mowat and Strobeck 2000). Clearly, using these methods to census population size would require inordinate field effort or, accepting a very conservative number as the census result. Alternatively, one could alter the sampling strategy in an effort to catch a greater proportion of the population such as working during a period when bears are highly clumped, for example along salmon streams. However, in the interior, trapping during the berry season when bears are clumped does not appear to improve the odds for a successful census. All studies that have trapped bears into the berry period in the interior have had poorer capture success than before the berry season (B. McLellan, pers. comm., Poole et al. 1999, Mowat and Strobeck 2000). Using hair removal inventories to census bears is only likely to be a reliable means to estimate population size in small areas with intensive sampling.

Using fewer trapping sessions would reduce the cost of inventories, especially for those projects where helicopters were used for access. However, many inventory projects done thus far achieved sample sizes that were marginally large enough to use the appropriate mark-recapture models. Thus, the effects of reduced precision should be investigated before reducing capture sessions. Much of the impetus for trapping 4-5 sessions during earlier studies was to allow the testing of model assumptions, and the selection of the most appropriate models using an objective model selection procedure (there are a number of mark-recapture models available). These earlier studies showed that capture probabilities for bears will often be too low to allow objective model selection (Boulanger 1998a, Poole et al. 1999, Mowat and Strobeck 2000). On the positive side, the investigation of capture variation revealed relatively low variation, compared to other

mammal work, though the power of the tests involved was probably not large (Mowat and Strobeck 2000). This suggests that variation in capture probabilities is modest when using the methods presented by workers like Woods et al. (1999) and Mowat and Strobeck (2000). There are exceptions to this observation and every effort should be made to avoid capture variation. Modest variation in capture probabilities would allow grizzly bear researchers to use simple time varying models such as Linclon-Petersen or Darroch's time model and not excessively violate assumptions. Both the above models are known to be robust to mild random capture variation (Otis et al. 1978). These models can generate population estimates with 2 or 3 trapping sessions; the more sophisticated models in program CAPTURE require, or work best with, 4 or more trapping sessions.

In addition, two alternative methods of tissue capture are available and warrant testing on bears in the event they prove more efficient than the bait site method. John Weaver (Wildlife Conservation International, Missoula, Montana) has developed a hair remover that entices the animal to rub on a pad and leave hair on nails on the periphery of the pad. These rub pads are simple to place and are effective for as long as the lure on the pad lasts, which is potentially many weeks. The second collection method involves the collection of scats. See details in section 8.2.

In this component of the research program we collected bear hair using two different methods and compared hair capture efficiency among methods. These results will be used to assess the usefulness of the method for managers who would ideally like to monitor population size of grizzly bears over many large areas through the range of the species. A particular focus was to assess whether rub pads may be able to supplement traditional bait stations to allow an increase in overall sampling efficiency.

Objectives

1. Estimate the abundance of grizzly bears in a roughly 5350 km^2 area of the Yellowhead ecosystem (see study area map Figure 1).
2. Compare the efficiency of barbed wire hair capture sites and carpet-tack hair capture sites for detecting bear visits.
3. Assess whether carpet-tack rub pads may catch bears that do not leave hair samples at bait sites.
4. Investigate the relationship between genotyping success and hair sample quality.

8.1.2 Methods

Study design

There is great variation in the extent and type of habitat mapping available for the study area. Currently, there is no grizzly bear habitat mapping for the north part of the study area (another component of this research project is assembling a complete grizzly bear habitat map using Landsat imagery and remote sensing tools). The centre of the pilot area (which is the largest portion) has HSI mapping by season prepared by BIOS (1996). The portion of Jasper National Park in the pilot area is also covered by the work (BIOS

1996). In addition, JNP has their own grizzly bear habitat quality mapping, and BC Environment grizzly capability mapping. Field crews used all available habitat maps to help with site selection. The more detailed maps from BIOS (1996) and JNP were particularly useful. The BC Environment capability mapping was too general to be much help in site level selection.

We divided the study area systematically into 64 cells and placed one baited hair snare site in each 9 km x 9 km cell. We trapped each cell for 3 14-day sessions, and moved each capture site > 1 km after each check. We began installing sites May 19, 1999 and finished the third check by 9 July. We selected hair snare sites that had the best potential to catch a bear at the time of setting. We used historical live capture success data from Russell et al. (1979), habitat mapping, and observation information collected during concurrent live-capture and subsequent radio telemetry to help us select sites.

Based on success observed in other studies, we felt we would need 90-100 hair removal sites per session to achieve adequate estimator precision (Mowat, in prep.). Therefore, in order to augment sample size and compare the effectiveness of rub pads and bait sites at removing bear hair, we selected 26 cells in which we independently installed rub pad hair capture stations along with bait sites. We sampled the 26 cells with the greatest volume of high quality spring and early summer habitat based on available bear habitat mapping. We alternated the installation of rub pad and hair sites for the 26 cells that contained both kinds of sites. All bait sites and rub pad sites were at least 1 km apart. We did not use rub pad sites during the third session because of poor capture success in the first 2 sessions. Instead we put a single rub pad on 1 of the trees supporting the barbed wire at all sites in the third session.

Field methods

Methods for capturing hair from grizzly bears at bait sites have been presented by Woods et al. (1999). We used liquid baits because they are easier and faster to install, and present less risk to the public because the potential to reward bears is removed. Liquid baits have been used for several other recent grizzly bear inventories with good capture success (Poole et al. 1999, Mowat and Strobeck 2000). We poured 1 cup of fish oil (fish rotted to a liquid) and 3 litres of rotted cow blood on wood piled up in the centre of each site (after Poole et al. 1999). In order to offer a novel scent in following sessions, we added beaver castor to each site during the second session and fennel oil during the third session. All hair from each barb was collected with bare hands and stored in paper envelopes and frozen as soon as possible following collection.

Rub pads were 15 x 15 cm squares of short carpet which had 1" roofing nails protruding through the carpet in a circle around the edge. The centre of the pad was baited with a lure meant to elicit grizzly bears to rub the centre of the pad and leave hair on the roofing nails in the process. Each roofing nail had short barbs of copper wire glued to the shaft of the nail which were meant to trap hair. Rub pad sites consisted of 4 rub pads nailed on nearby trees. We tried to put pads no more than 30 m apart and no less than 6 m apart. At the centre of the cluster of pads we hung a 30 cm square of carpet 3-4 m in a tree

which had been doused with long distance lure. We tried to put at least one of the rub pads from each site along an obvious game trail.

Intensive live capture effort using both aerial darting and leg snaring was conducted before and during our hair removal work. Bears were attracted to open areas and snare sites with large baits which were baited and maintained by both helicopter and road access (see section 6.0 Bear Capture and Handling). Grizzly bears were captured between 28 April and 20 June, 1999.

DNA analysis

Hair collected from each barb was treated as a single tissue sample during DNA analysis. Hair samples were examined for roots under a dissecting microscope; samples which had no roots or were obviously not bear were discarded. We used the roots of up to 10 hairs for extraction using QIAmp™ kits (Qiagen Inc., Ontario). We conducted species tests on each sample by amplifying a section of the control region of mtDNA and comparing the results to a reference collection (Woods et al. 1999). All grizzly bear samples were genotyped at 6 microsatellite loci. We assigned an individual identity to a sample when the sibling match probability was less than 0.05 (Woods et al. 1999). Live captured bears were also genotyped at 6 loci.

Data analysis methods

We used the mark-recapture models available in the program CAPTURE to generate a population estimate with confidence intervals (Otis et al. 1978). Data on the proportion of time individual radio collared bears spent on and off the study were used in the adjusted Petersen equation presented by Kenward et al. (1981) to estimate the bias caused by lack of topographic closure. We used likelihood ratio tests to compare detection success among helicopter and ground access sites and inside versus outside JNP. We used logistic regression to model the relationship between the number of and type of hairs that went into a sample and genotyping success.

8.1.3 Results

We collected 443 hair samples from bait sites during 3 trapping sessions starting 19 May and ending 9 July 1999. Mean trap duration increased during the third session because of access problems due to flooding (Table 23). We collected 19 hair samples from 52 rub pad sites set during the first 2 sessions and 2 samples from 62 rub pads during the third session.

Forty of 199 bait sites and none of the 52 rub pad sites removed grizzly bear hair during this study (Table 24). In the 26 cells which contained both rub pad and bait sites, 14 bait sites removed grizzly bear hair. Grizzly bear detections were not evenly distributed across the study area. In particular, we achieved very few detections in the Fiddle and Rocky river drainages in JNP. Detections were also rare in the northeast and southeast corners of the area (Figure 23). The number of sites which removed grizzly bear hair was lower in the third session and this is likely a result of the very poor weather during that

Table 23. Hair removal results from the Foothills Model Forest grizzly bear inventory, 1999. These results are for hair samples from all species.

Session	Start date	Mean duration (days ± SE)	Sites which collected hair samples	No. of samples	Mean hair samples/site (± SE)	New grizzly bear captures
rub pad sites						
1	24 May 199	12.7 (0.35)	3	6	2 (0)	0
2	3 June 1999	14.0 (0.25)	5	13	2.6 (0.68)	0
bait sites						
1	19 May 1999	13.5 (0.19)	22	133	6.0 (1.0)	17
2	2 June 1999	14.1 (0.12)	25	209	8.4 (1.3)	17
3	16 June 1999	15.8 (0.24)	13	101	7.8 (1.9)	6
Total			68	462		40

Table 24. Summary of sites which detected bears based on DNA species tests, Foothills Model Forest grizzly bear inventory, 1999.

	Grizzly bears	Black bears	Unknown[1]
Session	No. of sites	No. of sites	No. of sites
All barbed wire bait sites			
1	14	9	2
2	19	8	1
3	7	10	0
Total	40	27	3
Barbed wire bait sites for cells which contained rub pad sites			
1	8	4	0
2	6	4	0
Total	14	8	0
Rub pad scent sites			
1	0	2	1
2	0	2	1
Total	0	4	2

[1]these are the number of sites where no bear species was identified.

period. Fewer bait sites removed black bear hair while rub pads may have been more successful for black bears (Table 24). We were unable to identify a bear species at 3 of 72 bait sites and 2 of 6 rub pad sites that caught hair. These samples either lacked sufficient hair to perform the species test or, the sample was not bear hair.

We did not install independent rub pad sites during the third trapping session, instead we combined the 2 hair removal methods by hanging one rub pad on the periphery of each bait site. Six of the 7 combined sites which collected grizzly bear hair on the barbed wire failed to collect grizzly bear hair on the rub pad. The sample from the one rub pad that did collect hair failed to generate a genotype. Based on sign left at the site, two of 199 (1%) bait sites were approached by what may have been a bear but no hair sample was collected. In contrast, 14 of 52 (27%) rub pad sites were approached but no hair sample was collected, in most cases the rub pads were ripped down or chewed up. Ten rub pad sites had pads torn down, chewed, or gone. At least 3 sites had pads that were rubbed but failed to remove hair. In some instances bears seemed to prefer to lick the lure off rather than rub the pad. Rub pads were torn down in at least 3 instances at combined bait and rub pad sites during the third session.

We were twice as successful at removing grizzly bear hair at sites set using a helicopter (27% success versus 13% success, n=199, P=0.014) while our success rate at catching black bears was similar regardless of the type of access (12 versus 15%, n=199, P=0.52). We detected grizzly bears at 24% of the sites trapped in JNP and 18% of sites outside the park (Figure 23; n=193, P=0.28). Seventeen percent of sites in JNP detected black bears while 10 % detected black bears outside of the park (n=193, P=0.15).

We compared genotyping success with the number and type of hairs that went into a sample. Hair type was sorted into 5 categories that represented the relative proportion of guard hair or underfur in each sample. For example, category 1 was entirely underfur, category 3 was half underfur and half guard hair, and category five was all guard hair. The number of scoreable alleles per sample was positively related to both the number and type of hair in a sample (Figures 24 & 25; n=250, r=0.32, P=0.0001; n=250, r=0.38, P=0.0001 respectively). We used logistic regression to model the probability of scoring four or more alleles based on the type and number of hairs in the sample. Both the type and number of hairs were significantly related to genotyping success though the global model explained less than one third of the variance in the data (n=250, X2=42.0, 2 df, P=0.0001, rescaled r=0.52). The type of hair had a much larger effect on the probability of achieving a genotype than the number of hair (Table 25). For example, the probability of achieving a 4 loci genotype from one guard hair was 0.95 (95% CI 0.81-0.99) while the probability for 10 underfur was only 0.82 (CI 0.69-0.90). The probability of achieving a four loci genotype with one underfur was only 0.47 (CI 0.32-63).

We identified 40 different grizzly bears using hair removal and microsatellite genotyping. The 40 bears were captured 49 different times across 3 trapping sessions. Live capture crews captured 23 different grizzly bears; one bear was caught twice, 2 bears moved off the study area, and one handling mortality occurred. Fourteen grizzlies were captured during both live capture and hair removal work. Most live captures occurred before we

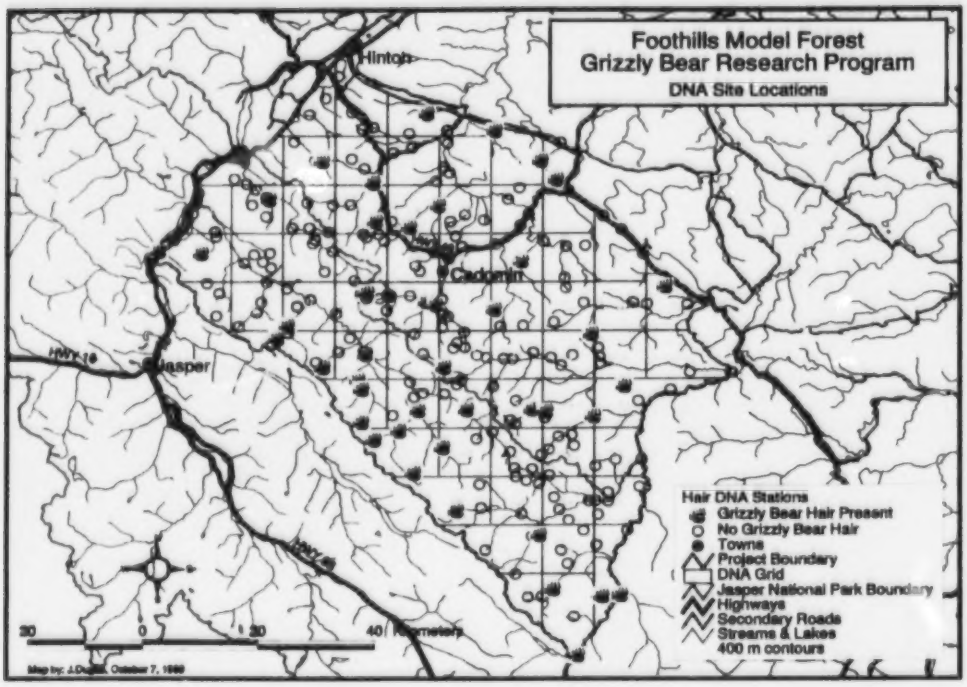


Figure 23. Map of the study area showing the location of hair removal bait sites including those sites which detected grizzly bears

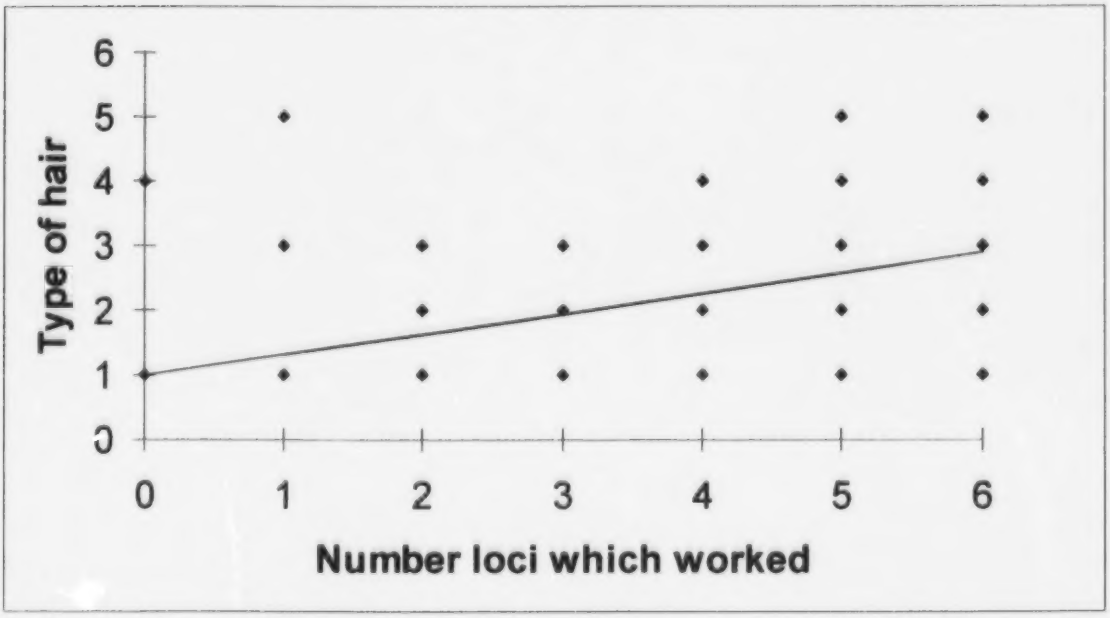


Figure 24. The relationship between the number of microsatellite loci scored and the type of hair used for DNA extraction. Hair class 1 signifies all underfur, class 5 is all guard hair, and intermediate classes are mixes of the two types based on relative proportions

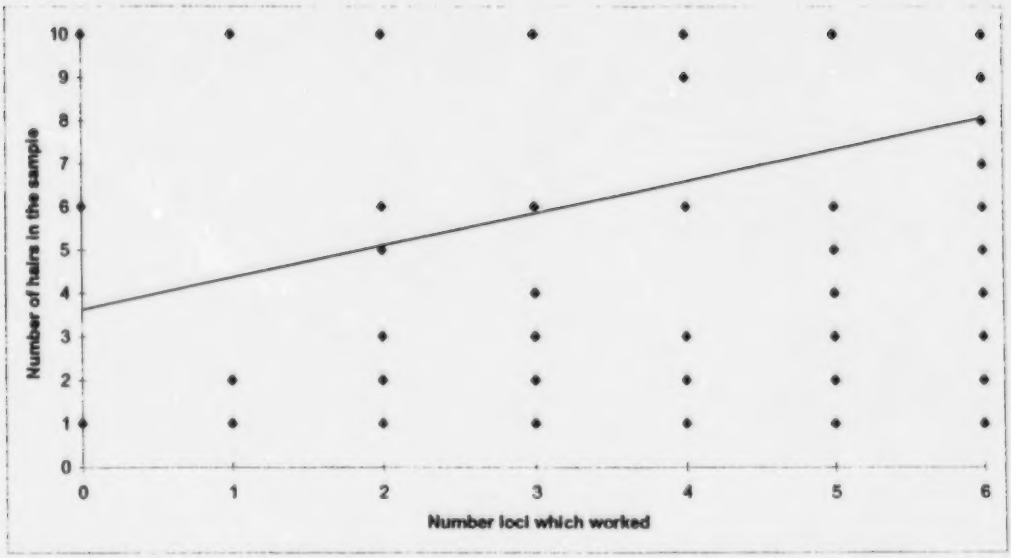


Figure 25. The relationship between the number of microsatellite loci scored and the number of hair used for DNA extraction.

Table 25. Probability of genotyping success based on a logistic model of the number and type of hairs that make up a hair sample. Genotyping success is defined as a sample that generates 4 or more scoreable alleles.

Number of roots	Type of hair	Probability of success	Lower CI	Upper CI
1	Underfur	0.47	0 32	0.63
5	Underfur	0.64	0.53	0.75
10	Underfur	0.82	0.69	0.90
2	Guard and under hair	0.69	0.56	0.80
5	Mostly underfur with few guard hairs	0.79	0.72	0.85
10	Mostly underfur with few guard hairs	0.90	0.84	0.95
1	Guard hair	0.95	0.81	0.99
5	Mostly guard hair with few underfur	0.95	0.87	0.98
10	Mostly guard hair with few underfur	0.98	0.94	0.99

began hair removal work though live capture effort continued into our second hair removal session.

The population estimate using bears identified at hair traps was 77 (95% CI 52-138) using Model M_t. We selected Darroch's time model because there was obvious variation in detection success among sessions (Table 1) and the goodness of fit tests in CAPTURE did not suggest strong heterogeneity nor behavioural response (Appendix 1). The heterogeneity model was not appropriate for this dataset because the number of recaptures was relatively small (Otis et al. 1978). We combined the live capture and hair capture datasets because live captured bears were captured in similar proportions to other bears. The average capture probability for radiocollared bears was 0.48 while the probability for bears that were never live captured was 0.27. There were 70 captures of 48 different bears in the combined dataset. In order to use the live captured bears for population estimation we created a fourth capture session (session 1); the new session began April 28 and ran until the beginning of our first hair removal session. The population estimate when live captured bears were included using model M_t was 68 (CI 55-90) with an average capture probability of 0.26.

The above population estimates are likely to be biased high because the assumption of geographic closure was unlikely to have been met (White et al. 1982). Correcting for closure is difficult though in this study we have measured the movement on and off the study area for a sample of bears using radio telemetry. We must assume that the movements of the radiocollared bears with respect to the study area boundary are representative of the entire resident population in order to use any of the following correction methods. None of the previously presented methods for correcting for closure in using radiotelemetry and mark-recapture data are particularly suited to this study. The methods of Kenward et al. (1981), Eberhardt (1990), and Garshelis (1992) require that radiocollared bears are marked before mark-recapture begins and that a large portion of resident bears is radio collared neither of which are the case in this study. All of the above methods essentially weight the point estimate by residency to correct for closure bias. In our case, there were sufficient locations (mean n=146, range 23-258) to estimate movement rates for 13 bears. These 13 bears spent 87.3% (SE 7.86) of their time on the study area, this includes one bear that moved east of the study area soon after capture. The simplest method to correct the previous estimate for closure bias is to multiply the point estimate and confidence intervals by 0.873 which equates to the time based correction given by Kenward et al. (1981). This simplistic correction factor does not incorporate the sampling error in measuring residency, nor the variability in residency among animals. Garshelis (1992) presented a correction method where he weighted each individual bear by their residency during each trapping period though he found little difference between his method and the method used here except when there was a significant difference between residency among bears caught once and recaptured bears. The final estimate for this study area is then 59 bears (CI 48-79) which equates to a density estimate of 11 bears/1000 km^2. Note that we identified 48 different bears on this study area during live capture and hair sampling.

8.1.4 Discussion

The number grizzly bears detected at hair removal sites during this study was sufficient to generate a population estimate though the CI for the estimate was large (±56% of point estimate). The third trapping session was plagued by unusually deep snowfall (about 45 cm at 1800 m) early in the session and torrential rains later in the session. This precipitation caused bears to move away from preferred seasonal habitats reducing our capture success and, rain and snow likely knocked hair off the barbed wire reducing our chances of identifying a bear. Several of our sites were completely submerged in water or covered in snow. This type of event highlights the risk of using only 2 sessions for a mark-recapture inventory (Mowat in prep.). Very low capture success during 1 session of a 2 session inventory would negate the estimation of population size. In the case of a 3 session project one can always base an estimate on the 2 sessions which had reasonable capture success which is essentially what we have done here.

Grizzly bear capture success was further limited because rub pads sites did not remove hair from grizzly bears during this study. Many sites were approached by bears but simply failed to remove any recoverable hair samples. Black bears seemed more willing to rub on the pads, though rub pad sites did not appear as efficient at collecting black bear samples as bait sites. Installing a rub pad at our bait sites during the third session did not capture any grizzlies or black bears which were not captured on the barbed wire though only 7 of these combined sites caught grizzly bears in this session. One bait site with a rub pad was probably approached by a bear but failed to capture a sample and the rub pad was torn down.

Why were rub pads so ineffective at removing bear hair? Workers in Montana, Idaho, and Washington have consistently removed black bear hair using rub pads baited for lynx, and these sites were not baited with a long range attractant as our rub pad sites were. We used a somewhat different lure than used for lynx but this lure was tested on captive grizzlies and it caused all captive bears to rub on the pads (John Weaver, pers. comm.). Wild grizzlies seemed more likely to rip the rub pad down and chew it up than rub on it. Perhaps the scent contained too much fish oil and this caused bears to chew the pad rather than rub it (John Weaver, pers. comm.). Black bears may be more willing to rub the pads in general, they did not appear to rip pads down as often as grizzlies. The lower overall success for black bears at rub pad sites may be due to the fact that the liquid baits used at baits sites were much stronger smelling than the long distance attractant used at rub pad sites and not due to reduced efficiency of the rub pads.

We demonstrate that genotyping success is strongly linked to the number and type of hairs that go into a sample. This result is not surprising and concurs with work by Gossens et al. (1999) and Boulanger (1998b). It is interesting to note that when the number of hairs are few the type of hair, guard versus underfur, has a greater affect on probability of genotyping success. Using our laboratory methods, hair samples of 5 or less underfur have little more than 50% chance of scoring 4 or more loci and may not warrant the genotyping effort. We did not measure variables that may affect DNA degradation such as the length of time a hair sample stayed in the field, the humidity during exposure, and the hair storage method. Foran et al. (1997) suggest these variables

are important to genotyping success and further investigation of the affects of DNA degradation on genotyping success are to be encouraged. There were certainly other factors that affected genotyping success in our data as demonstrated by the rather weak overall fit of our logistic model.

Russell et al. (1979) reported grizzly bear density as 10-12 bears/1000 km^2 for what amounts to the JNP portion of our study area. We found essentially the same density of grizzly bears on our study area 22 years later. However, our study area included a large portion of boreal plains habitat and an area of JNP north of the Russell et al. (1979) study area in which we detected almost no bears. The current density of bears in the former Russell et al. (1979) study area is likely to be greater than our mean density, though our sample sizes are too small to test this empirically. Other population studies on grizzly bears on the east side of the Rocky Mountains were conducted in the west-central portion of Alberta. Estimated densities of grizzly bears in these study areas ranged from 4.6 bears/1,000 km^2 in the Berland-Wildhay rivers region, to 7.4/1,000 km^2 in the areas of the South Wapiti River, and to 7.4-9.6/1,000 km^2 in the Swan Hills study (Nagy and Gunson 1990). These estimates are mildly lower than our density estimate. Poole et al. (1999) estimated grizzly bear density on the Rocky mountain east slopes of northeast British Columbia. Their estimate for the boreal plains portion of their study area was the same as the density found on our study area (10 bears/1,000 km^2). However, Poole at al. (1999) reported a much higher density in the mountainous portion of their study area (35 bears/1,000 km^2). Larsen and Markel (1989) and Pearson (1975) also reported higher bear densities than those reported here in the boreal mountains region of southern Yukon.

We are conducting ongoing analysis with this data set (DNA-hair) along with our 1999 radio telemetry data set in order to further investigate two primary issues; capture probability and population closure. These analyses are ongoing and will be presented in subsequent reports. The results of these analysis will help guide future fieldwork related to DNA collection.

8.2 DNA Scat Extractions

Investigators: Dr. Sam Wasser and Gordon Stenhouse

8.2.1 Introduction

Some of the most critical questions in wildlife conservation and management require knowledge of sex-specific animal abundance, genetic diversity, gene flow and physiological impacts of environmental disturbance, each geographically mapped along with landscape characteristics. DNA and hormone measures can provide valuable biological tools for these purposes. However, samples used to access this information must be readily acquired. This need for high sample accessibility has led to a recent growth in application of noninvasive DNA and hormone techniques. For example, several researchers have been using DNA from hair to estimate population sizes, systematically collected at hair snag stations throughout a study area in a mark-recapture study design (e.g. Woods et al 1999; Koehler 1997, Morin et al 1993). Fecal DNA has been used to determine brown bear densities in France (Taberlet et al 1997). Fecal stress

hormones have been used to measure impacts of human disturbance on endangered spotted owls (Wasser et al 1997a), African elephants (Foley, in review) and Rocky Mountain Elk (Millspaugh et al, in prep). Because DNA from feces can be used to determine individual identities, fecal samples can also provide repeated hormonal measures of physiological stress from the same individual in response to environmental disturbance. New methods using specially trained scat detection dogs to enhance sampling efficiency and reduce collection biases (Wasser et al in prep) makes this methodology all the more powerful

8.2.2 Methods

As previously described in section 8.1, sixty four 9 X 9 km grids were distributed across the study area (Figure 26), with one hair snag station positioned in each 9 X 9 km grid during the three sampling sessions. We used trained scat sniffing dogs (SSD's) (see dog training section below) to search a distinct predetermined route (transect) in 40 of the 64 hair snag locations. These 40 sites were selected from the 64 sites in an effort to address logistical constraints with access into portions of the study area. The detection dogs searched the predetermined route which was selected based on exiting knowledge of bear habitat within each grid cell. Search routes were between 5-9 kms. in length. Search routes were always > 0.5 mi. from established hair snag sites. Dogs worked on a 10 ft. lead, allowing them to travel a specified distance off the transect route as long as they clearly had scent. We then returned to the point where we left the transect route and continue the search. For transect sampling, detection was limited to 13m on either side of the transect line. Speed of coverage was reduced with increasingly complex terrain and poor wind and weather conditions. When terrain was more complex, the handler had to be aware of dead air space and work these areas accordingly. Searches were called off for the day whenever weather conditions were extremely poor (e.g., very high winds or downpour).

Each hair snag site was moved a total of two times over a 1.5 month period within its 9 X 9 km grid (once every 14 days). The search routes were unique during each sampling period. Overall the dogs sampled 40 grid cells during 3 sampling periods (40x3=120).

There were 4 dog teams used during the 1999 field season. Each team consisted of a trained dog, an orienteer whose role was to follow the predetermined route and GPS'd the location of scat samples, and a dog handler who worked with the dog and collected all bear scat samples found.

All fecal samples were processed in the field for hormone and DNA preservation using the respective methods described by Wasser et al (1988; 1997b). Scat samples were divided into two packages. One of these was simply mixed, labeled and stored in a whirl-pac sample bag and then frozen when the team returned to the lab that same day. The other sample was well mixed with a sterile tongue depressor; 10 g of sample was then placed in a water and air tight vial containing silica gel at a ratio of 4 g silica per g feces.

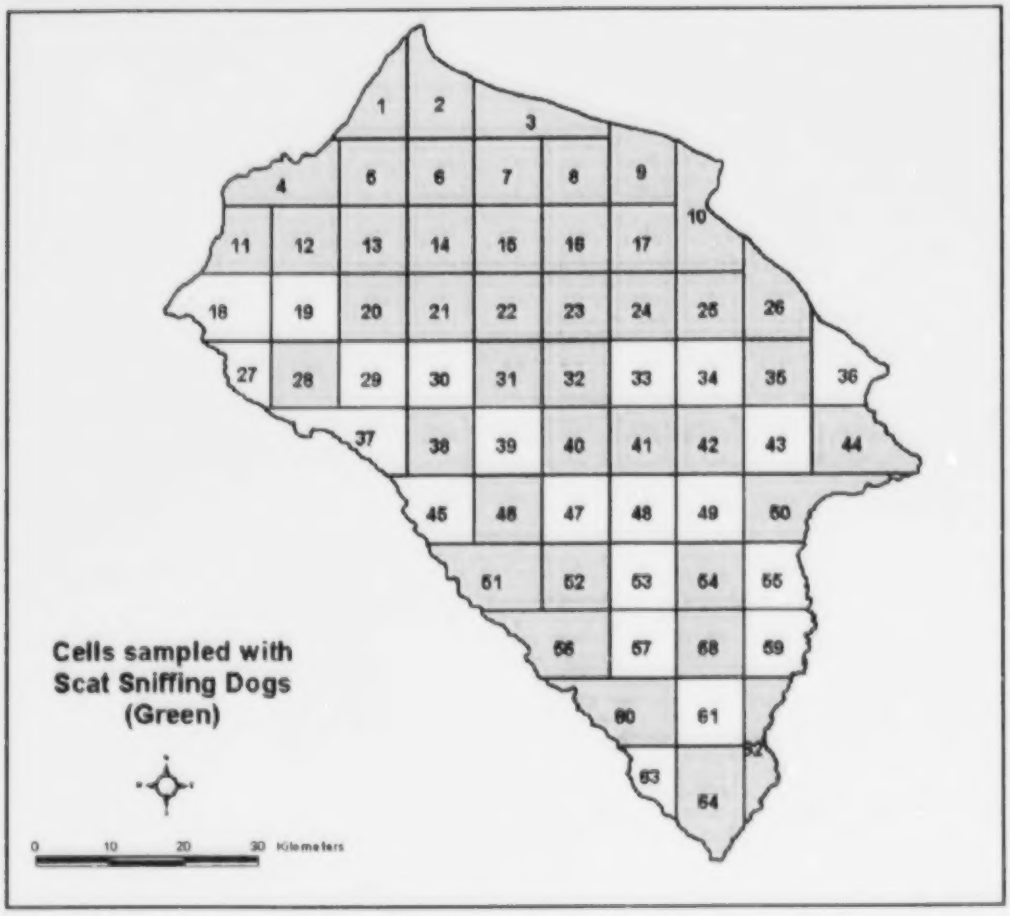


Figure 26. 9X9 km grids distributed across the study area; cells in green were sampled by the scat sniffing dogs.

SSD Training

Each of our scat sniffing dogs (SSDs) and handlers began their training as part of the Narcotics Detection K-9 program at McNeil Island Correctional Center in Washington. All training was overseen by Sergeant Barbara Davenport, the head trainer of the K-9 unit. Dogs were initially introduced to marijuana through the use of a scent box. The scent box has five compartments, each with a 5 cm hole opening to the outside. Marijuana is placed in one of the 5 compartments. The dog was then guided to each hole and rewarded with a well-timed toss of a ball and verbal praise immediately upon sniffing the correct hole. The dog quickly learned to associate sample detection with this reward, becoming highly motivated to do the work. We then paired sample detection with a sit response required prior to receiving the reward. This added an additional cue to the handler that a sample has been detected and also reduces the chances of the dog disturbing the sample. Containers holding marijuana were then hidden throughout an indoor room and the dog taught to search for the sample while guided by its handler. This was followed by outdoor searches over a confined area. After 1-2 weeks, the dog had become very adept at searching for and finding the target samples. At this time the handler has become adept at reading the dogs change of behavior, once it has detected the specified odor, and then working the dog to the source. At this point, we used the scent box to introduce the dog to scat samples of one of the target species. The pairing occurs almost immediately. Scat samples were next hidden over a progressively larger area in the field. During the first few days the handler was aware of where samples were hidden. We then hid samples without handler knowledge, documenting sample detection rates throughout the entire process.

As training proceeded, we progressively increase the complexity of weather and terrain conditions under which training occurred. Weather conditions varied from wet to dry, hot to cold, windy to calm and up-wind to down-wind. Terrain varied from open to wooded areas, in and around ravines, included streams with flowing water, and dense vegetation. We also proofed each dog against alerting to scat from species we did not wish them to detect, but are sympatric in the study area. This was done the same way as when introducing scat from a new target species except that a correction was given if the dog alerted to the nontarget species scat (snap of the choke collar with the verbal command, leave it followed by a verbal reward when the sample is abandoned). Since scat odor from a given species differs between individuals and diets, the dogs were also trained to generalize across individuals and diets for a given species. Dogs were, accordingly, introduced to scat from many different individual bears, across a variety of diets/seasons. These scats are obtained from multiple wild grizzly and black bear in Glacier and Jasper National Parks and other bear rich areas throughout the Pacific Northwest.

Laboratory Procedures

DNA Extraction

Fecal DNA is extracted based on the method described in Wasser et al (1997b). Briefly, 600 l of Qiagen Load Buffer (QLB: 500 mM Tris-HCl, 16 mM EDTA, 100 mM NaCl, pH 6.0) is added to 100 mg of freeze-dried feces. Samples are vortexed briefly and then

centrifuged at 13,000 rpm for six minutes. Four hundred microliters of supernatant is transferred to a fresh tube, 400 l of AL buffer and 50 l of Proteinase K are added, and the mixture incubated for 16 hours at 37C. After adding 420 l of ethanol, lysates are loaded in two centrifugations onto the spin columns, washed and eluted in 100 l of 10mM Tris HCL, pH 9.0. All samples are then purified using glass milk (GenecleanSpin Kit, Bio 101, Inc., Vista, CA) to remove any potential inhibitors (Wasser et al 1997b). PCR amplification and visualization of all loci are the same as those described for hair (Paetkau et al. 1995).

Fecal hormone extractions

We have extensively tested extraction methods and solvents for use with feces. Until recently (4/98), fecal samples were boiled for 20 min. in 5 mls 90% ethanol. In mid-1998, we switched to a less labor-intensive shaking method, extracting samples in 90% methanol on a pulsing vortexer (see below). This method is far less labor and time intensive, yet provides extraction recoveries equivalent to our older method. Desiccated samples are ground, sifted through a steel mesh, and thoroughly mixed. Approximately 0.2g of each dried sample (the exact weight is recorded) is placed in a 16x125mm labeled test tube. 2.0 ml of 90% methanol is added to each sample and the tubes are capped. The samples are loaded into a pulsing vortexer (Glas-Col Multipulse Vortexer), and are vortexed at high speed for 30 minutes. This machine interrupts the vortexing action briefly every few seconds to jolt any heavy fecal fragments into motion. After the 30 minutes of vortexing, the samples are centrifuged at ~2200 rpm for 20 minutes. The methanol supernatant (containing steroids) is transferred to labeled cryovials with tight-fitting screw-top caps with O-rings (since methanol is volatile, it is important to have vaporproof caps). This "1:2" dilution supernatant, or extract (e.g., steroids from the weighed feces are now dissolved in 2 mls of methanol) can be stored at -20C for months or years as long as no evaporation occurs. The above extraction technique consistently recovers about 90% of the steroids in the original sample, as measured by validations with 3-H labeled estradiol, testosterone, progesterone and cortisol. 125-I corticosterone assayIn the corticosterone assay kit [ICN Biomedicals, Inc. in Costa Mesa, CA (800-854-0530)], 50 ul of each (diluted) sample and standard is pipetted to duplicate assay tubes. (There are 6 standards spanning 0.125-5.0 ng/ml.) 100 ul of corticosterone antibody and 100 ul of 125-I labeled corticosterone is then added to the appropriate tubes. All tubes are vortexed and are incubated at room temperature for a minimum of 2 hours. After incubation, 250ul of corticosterone precipitant (a second antibody) is added to all tubes except the total-counts tubes. All tubes except the total-counts tubes are centrifuged for 20 min. at ~2200 rpm in a refrigerated centrifuge, and are then immediately decanted into a waste bottle. The tubes are left upside-down on blotter paper for 2 min.; the tops are blotted dry; the tubes, with the precipitates, are then counted for 2.00 min. in a Packard Crystal gamma counter. Hormone concentrations are determined by comparing counts/sample to those on a standard curve, suing the Packard Crystal gamma counter's built-in program, with a logistic curve fit. ICN's data for variation of the corticosterone assay is: mean intra-assay CV of 7.3%, mean inter-assay variation of 6.9%.

Fecal DNA Measures

Fecal DNA preservation methods have been examined over periods ranging from weeks to months (Wasser et al 1997b). The quality of fecal DNA, as indicated by PCR amplifiability, was preserved to varying degrees depending on the preservation technique used. Silica (sil) consistently fared best among the drying preservation methods at a ratio of 4g silica/g feces, following by freeze drying (FD) and Drierite (Dri) for all types of DNA examined, at all temperatures. Lower ratios of silica to feces were also tried but performed less well; higher ratios (8:1) performed comparably to the 4:1 ratio. Similarly, increasing the container surface area (up to 4.5 cm in width) improved the quality of the silica preservation technique. Separating the silica from feces with filter paper also provided a higher quality amplification product than simply mixing silica and feces together (data not shown). Combining drying techniques (e.g., FD plus sil) did not notably improve DNA preservation.

Fecal Hormone Measures

In the mid-1980s, Wasser and colleagues began pioneering techniques to measure steroid hormones in feces of free-ranging wildlife (Wasser et al 1988, 1993, 1994, 1996, 1997a; Wasser 1995, 1996). We have since successfully measured stress and reproductive steroids in a wide variety of mammals, including baboons, macaques, sun bears, sea otters, maned wolves, wild dogs, a variety of cat species, elephants, moose, elk, spotted owls and more (Brown et al 1993; Long et al 1996; Monfort et al 1993, 1997; Wasser 1995; Wasser et al 1995, 1996, 1997). As part of this research, we also developed means to preserve samples in the field without freezing and eliminate impacts of urinary contamination of fecal samples by storing samples in 90% ethanol (Wasser et al 1988). Dietary changes in hormone excretion were also controlled by freeze drying samples and expressing hormone concentrations per gm dry weight (Wasser et al 1993). More recently, we showed that desiccating samples in silica, followed by oven drying provides even better hormone preservation without freezing than does ethanol. This is the same method that worked best for preservation of DNA, allowing us to preserve the same sample for both DNA and hormone analyses.

A combination of radiolabel infusion and adrenocorticotropic hormone (ACTH) challenge studies were used to validate a fecal cortisol metabolite assay for mammals. ACTH is the anterior pituitary hormone that is secreted in response to stress, causing the adrenal cortex to release the stress hormone cortisol. I.v. injection of ACTH causes a rapid and maximum release of cortisol in serum that returns to baseline within a few hours. This pattern was expected to be mimicked in feces, delayed by the time lag from secretion of the hormone in blood until its excretion in feces, as defined by the radiolabel infusion study. The ICN I125 corticosterone antibody (Ab) had the highest affinities for the fecal cortisol metabolites across all species tested, and hence showed the predicted ACTH challenge pattern at the appropriate time course

8.2.3 Results

TBA

9.0 Habitat Mapping

In 1999 progress in some areas related to this project component has been made as a result of the combination of funding/support from the CCRS RSDDP contract to GeoAnalytic Inc. and the Foothills Model Forest Grizzly Bear Research Project:

1) a classification structure for bear habitat mapping has been identified;
2) a test of the evidential reasoning software has been completed;
3) a compilation of the available satellite imagery, GIS data, and field observations related to habitat mapping has been completed;
4) a number of important protocols, for example, for integration GIS and GPS bear movement data have been written and tested;
5) a test of the Patch Analyst (Elke et al 1999) Arc/View software extension has been completed; and
6) as part of the Alberta Forest Biodiversity Monitoring Program Pilot Study, a preliminary example of the use and form of landscape metrics in areas of varying degrees of disturbance in the study area has been generated.

10.0 GIS Applications

The GIS component of the program has been successful in integrating field data, such as the grizzly bear GPS-radio collar locations, into the GIS system. Detailed procedures and data-checking steps are now in place and will ensure consistency and efficiency in the upcoming field seasons. The digital data has been used for data and spatial analyses including grizzly bear road crossings, distances from roads, etc.

New data sets have been or will be acquired. These include: recent Landsat TM imagery, 1998 IRS imagery (5m, panchromatic), Weldwood and crown land Alberta Vegetation Inventory (AVI), Weldwood's Ecological Land Classification (ELC) and updated provincial digital base data. The digital data will aid in new analyses including quantifying landscape change over time in terms of grizzly bear habitat suitability and potential.

Two students from the British Columbia Institute of Technology (BCIT) are working on a project to create a realistic 3-d landscape visualization tool. This tool will incorporate satellite imagery and spatial data to demonstrate to land managers the movement patterns of radio-collared grizzly bears within the study area. This project is supervised by the FMF GIS staff and, if successful, will provide an effective communication tool for the program.

11.0 Communications

Communication and understanding are critical is industry, government, and the public are to play a role in sustainable forest management and a healthy grizzly bear population. Research and stewardship often goes unrecognized by the public, often because it is done

quietly and without fanfare. Foothills Model Forest believes that communication builds understanding and support, and is dedicated to delivering a well-rounded program to that end. A long-term communications strategy is developed for Foothills Model Forest. Annual communication work plans are developed for Foothills Model Forest as well as the grizzly bear research project. Foothills Model Forest understands and is committed to communicating a sustainable forest management message.

The key messages of the Foothills Model Forest Grizzly Bear Project are as follows:

- **Sustainable Grizzly Population**

The goal of the research project is to provide land and resource managers with common and consistent data and analysis, and planning and management tools to help ensure the long-term conservation of grizzly bears in the Alberta Yellowhead Ecosystem.

- **Partnerships**

Successful conservation of the Grizzly Bear requires a cooperative, integrated approach by government, industry, scientists, associations and key stakeholders.

- **Grizzly Bears are an Indicator Species**

Grizzly bears are regarded as an "indicator" and "umbrella" species. They are widely regarded as a species with very poor resiliency to stress, therefore provide a reliable indicator of ecosystem health. They are an "umbrella" species since the maintenance of landscape conditions favourable for grizzly bears result in conditions beneficial to a wide range of other wildlife.

- **Stewardship**

The conservation of grizzly bear populations is an ongoing process and will require the long-term commitment and participation of land and resource managers along with the overall support of the public.

In 1999 efforts were made to communicate the above messages to partners, general public and key stakeholders. Communication activities have been successful. The two biggest accomplishments were making the front page of the Edmonton Journal and being featured on The Discovery Channel. This will continue, and be expanded. Other accomplishments are:

- Feature story in Edmonton Sunday's Sun.
- Electronic media - evening news on CBC (French and English), CTV, ITV, A Channel TV News; Big Bear Radio Station (FM - Drayton Valley), CBC radio (French and English).
- Research program noted in other Edmonton Journal Articles, for example Ed Struzik's stories on endangered species.
- Research forum that provided an opportunity for stakeholder groups to provide input into the program.
- Included in Foothills Model Forest communication products like newsletters, annual reports, web site, print advertisements.

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Appendix A

Veterinary Reports Associated with Grizzly Bear Handling during the 1999 Capture Period

Prepared by Drs. Marc Cattet and Nigel Caulkett (DVM)
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Progress Report: Sub Project One

Title: Comparative Immobilization of Free-Ranging Grizzly Bears with Zolazepam-Tiletamine and Xylazine-Zolazepam-Tiletamine

Objective: To determine and compare the efficacy and behavioral and physiologic effects of two drug combinations, zolazepam-tiletamine (ZT) and xylazine-zolazepam-tiletamine (XZT), for the immobilization of grizzly bears.

Progress: Twenty-three grizzly bears were captured for the Foothills Model Forest Grizzly Bear Project during May and June 1999. Chemical immobilization was required for all captures with ZT used to anesthetize 16 bears and XZT used to anesthetize 7 bears (Table 1). XZT appeared to be a more potent drug combination as it immobilized grizzly bears at significantly lower doses than was required with ZT. As a consequence of its efficacy at lower doses, XZT could be administered to bears in a smaller volume than needed with ZT. This finding may be of significance to the health of captured bears as muscle damage at the injection site is, in part, a direct function of the volume of drug administered. Furthermore, the comparatively small volume of XZT that was required to affect immobilization allows the possibility in future of using drug delivery darts that are air- or gas-activated rather than the currently-used darts (Cap-Chur® and Pneu-Dart®) that inject drugs with explosive discharge mechanisms. The former type of dart causes significantly less tissue damage than the the latter type, but is manufactured to contain smaller volumes of drug than typically required to immobilize grizzly bears.

The two drugs had very different effects on the behavior of bears during the induction of anesthesia and during the handling and sampling period that followed. During induction, bears injected with ZT typically stumbled as incoordination developed first in the hindlimbs and then in the forelimbs. In contrast, bears injected with XZT appeared to maintain full coordination until the drug effect increased to a point where they would slowly sink into recumbency. Different effects of the two drugs on the behavior of bears during handling suggested bears immobilized with ZT were in a lighter state of anesthesia than bears anesthetized with XZT. Bears anesthetized with ZT tended to have rigid limbs, increased salivation, and occasional movement of jaw and eyelids, all of which intensified with noxious stimulation (e.g., premolar tooth extraction, application of ear radio transmitter). In contrast, bears anesthetized with XZT were posturally flaccid, their eyes assuming a fixed stare. Furthermore, bears anesthetized with XZT showed little or no response to noxious stimuli.

The physiological response of grizzly bears to anesthesia varied widely among individual bears, but differed between drugs and, similar to the behavioral effects, suggested that bears immobilized with ZT were in a lighter state of anesthesia than bears anesthetized with XZT (Fig. 1). Heart and respiratory rates tended to be slow with XZT, maintained at rates that might be expected in a resting and relaxed bear. XZT also appeared to cause a gradual, albeit not statistically significant, increase in body temperature. In contrast, heart and respiratory rates in bears anesthetized with ZT were maintained at rates more typical of an active bear, and there were no trends apparent in the rectal temperature

values over time. These physiological findings were consistent with similar observations on the effects of these drugs in polar bears (Cattet et al., unpublished report). Despite their different physiological effects, both drugs were safely tolerated by grizzly bears as there was no evidence of adverse response to either drug.

The physiological effects of XZT were effectively terminated by administering the reversal drug, yohimbine (Table 1). There is presently no reversal drug available for ZT.

Recommendations for 2000:

- test the reliability of an air- or gas-activated drug delivery dart system (Paxarms®) for immobilizing grizzly bears. Initial testing should be restricted only to bears captured by leg-hold snare.
- increase the spectrum of physiological data to include blood pressures and hemoglobin oxygen saturation, as well as heart and respiratory rates and rectal temperature.
- continue comparing the efficacy and behavioral and physiologic effects of ZT and XZT in grizzly bears with the goal of gathering an adequate quantity of data to prepare a report for publication in the scientific literature

Progress Report: Sub Project Two

Title: Nerve Block Techniques in Free-Ranging Grizzly Bears

Objective: To develop nerve block techniques in grizzly bears that provide adequate analgesia for the application of lip tattoos and extraction of premolar teeth.

Progress: This project was initially planned to begin during 1999. However, the existing study protocol could not be efficiently incorporated with other sampling and handling procedures that were being conducted with immobilized grizzly bears. Therefore, it was decided that the protocol for this sub project would be modified and the sub project would be initiated during the spring of 2000. The modifications to be made are as follows:

- tattoos will no longer be applied to the inside surface of lips, but will instead be applied to the skin on the inside of the thigh. Applying tattoos at this location will be comparatively less painful than the lip, and will not require the administration of a nerve block.
- the nerve block for removal of a premolar tooth will be administered at the site of the mandibular mental foramina instead of in the area of the mandibular nerve foramen, as was formerly proposed. The mental foramina are easily located on a grizzly bear and should permit the quick application of a nerve block that will effectively remove the pain associated with the extraction of premolar teeth.

The Health of Captured Grizzly Bears

During 1999, the health of captured grizzly bears was evaluated through the measurement and monitoring of their physiological response to immobilization and handling, and through the collection and analysis of their blood.

Physiological response: The physiological response of grizzly bears to immobilization and handling has been largely described under the progress report for "Sub Project One". To re-iterate, both anesthetic drugs (ZT and XZT) appeared to be safely tolerated by grizzly bears as there was no evidence of adverse response to either drug. Nevertheless, there were aspects of the capture and handling operations (aside the anesthesic drugs) that did compromise the health of two animals. An adult male of unknown age that was captured in a leg-hold snare died within minutes after an immobilizing dart fired from a rifle hit it in the chest. A necropsy was conducted and indicated that the dart needle had lacerated one of the coronary arteries resulting in severe hemorrhage and cardiac failure. Another adult male (G-14; 9 year-old) injured its left hind foot after stepping into a leg-hold snare that was set along a trail. Following both these events, reports were immediately prepared to describe the details surrounding each incident. The reports were subsequently reviewed to make recommendations and take action to avoid similar events from occurring again.

The assessment of physiological parameters (heart and respiratory rates, rectal temperature) was initiated as soon as an immobilized bear could be safely approached and re-evaluated every 10 to 15 minutes throughout the duration of handling. Initial measurements were often recorded within 10 to 15 minutes of a bear being immobilized, irrespective of whether the bear was captured by leg-hold snare or by aerial darting. However, during aerial darting operations when the helicopter was carrying more than three people, initial measurements were often not recorded until 20 to 45 minutes after a bear was immobilized. This longer approach time was required because it was necessary for the helicopter to land and drop off additional personnel before proceeding to dart a bear. Then, after a bear was darted and completely immobilized, it was necessary for the helicopter to return and pick up the dropped-off personnel prior to the immobilized bear being approached. This prolonged approach time raises concern for the safety of immobilized bears and effort should be directed in future toward keeping the approach time as short as possible without jeopardizing the safety of field personnel.

Blood analyses: Blood samples were collected from 18 of 23 captured grizzly bears and analyzed for hematology (i.e., numbers and characteristics of blood cells) and serum biochemistry. The hematology results could not be interpreted reliably due to changes in the numbers and characteristics of blood cells which occurred in the time between the collection and the analysis of the blood. The blood serum was much less affected by handling and storage than were the blood cells and could, therefore, be analyzed and the biochemistry results interpreted with greater confidence (Tables 2 and 4).

The interpretation of the serum biochemistry of most wild species is difficult relative to that of humans and domestic mammals because reference ranges based on animals of

normal health are often unavailable. For this project, the serum biochemistry of grizzly bears was analyzed and compared using three approaches. First, the serum biochemistry ranges for grizzly bears captured during this project were compared to ranges of values measured for grizzly bears captured during two previous projects in other geographical locations (Table 2). Second, bears were assigned to groups based on the method of capture used (snare versus aerial darting) and the anesthetic drug administered (ZT versus XZT) and comparisons of ranges of values for different blood parameters were made among groups (Table 3). Third, a health assessment was made for each individual bear captured during 1999 by interpreting their serum biochemistry relative to reference ranges established for domestic dogs and cats (Table 4).

The serum biochemistry values for grizzly bears captured during this project were similar to the ranges of values reported for two previous projects (Table 2). Relative to domestic mammals (e.g., dog and cat), the reference ranges of most individual parameters in grizzly bears are often large; a feature which is consistent among all three projects. Much of this larger variation in grizzly bears when compared to domestic mammals is likely explained by differences between wild and domestic mammals in the methods by which they are handled and how their blood is collected and stored. It follows that the evaluation of the health of grizzly bears based on serum biochemistry must be made with consideration of the factors external to the animal including the method of capture, the anesthetic drugs used, and the method by which blood is collected, stored, and processed.

The serum biochemistry of grizzly bears appeared to be largely affected by the method of capture used (Table 3). Bears captured by leg-hold snare had greater serum concentrations of sodium, chloride, alanine aminotransferase (ALT), creatine kinase (CK), and lipase than did bears captured by aerial darting. Furthermore, total cortisol concentrations tended to be greater (although not statistically significant) in bears captured by snare. Greater concentrations of serum sodium and chloride in snared bears were likely due to a combination of mild water loss associated with panting and a lack of available water to drink. Greater concentrations of ALT and CK were attributed to muscle injury associated with the snaring and, in particular, the exertion that bears typically expended to escape the snare. The higher cortisol concentration in snared bears was likely in response to the stress associated with being physically restrained and, in some cases, being injured. The significance of a higher lipase concentration in snared bears was not certain, but may have been induced by the high concentration of serum cortisol.

In contrast to snared bears, bears captured by aerial-darting had greater serum concentrations of calcium and creatinine (Table 3). These biochemical differences were more likely an effect of the date of capture rather than the method of capture. The capture of bears by aerial-darting occurred primarily during the early part of May, within weeks of bears emerging from their winter dens. Most bears at this time of year would be expected to be in a fasting state and, consistent with this state, would be expected to have high serum concentrations of creatinine and calcium (due to reduced urine excretion). In contrast, the capture of bears by snare was concentrated toward the latter part of May, and through the month of June, when most bears were likely feeding.

Health assessments for captured grizzly bears are presented in Table 4. The interpretation of the serum biochemistry for the individual animals is tentative, and may not be correct in all cases. This is because interpretations were made relative to reference ranges established for domestic dogs and cats. As the biochemistry data for grizzly bears increases in the coming years, it will be likely that reference ranges can be established for this species allowing health assessments (based on serum biochemistry) to be made with a greater degree of confidence than is currently possible.

Recommendations for 2000:

- whenever possible, bears captured by leg-hold snare should be administered anesthetic drug by blow pipe rather than by dart rifle.
- test the reliability of an air- or gas-activated drug delivery dart system (Paxarms®) for immobilizing grizzly bears captured by leg-hold snare.
- investigate the effectiveness of using bait which contains a sedative (e.g., acepromazine granules in honey smeared on the anchor tree) to reduce the occurrence of stress and injury in bears captured by leg-hold snare.
- immobilized bears should be approached quickly and safely, irrespective of the method of capture. For aerial-darting, this will require the number of helicopter personnel to not exceed three people (i.e., the number of people that can safely remain in the helicopter during a darting procedure).
- arrangements should be made to ensure that hematological analyses of grizzly bear blood samples are done as soon as possible following blood collection. This could be accomplished by arranging to have the hematology completed on a day-to-day basis by the clinical laboratory at the Hinton Health Centre.

Table 1. Immobilization features of Telazol® (ZT) and a combination of xylazine and Telazol® (XZT) in grizzly bears captured for the Foothills Model Forest Grizzly Bear Project during May and June 1999.[a]

Feature[b]	ZT (n = 17)	XZT (n = 10)
1. Induction		
dose (mg)	905±70 *	623±76 *
dosage (mg/kg)[c]	11.1±1.2 **	5.6±0.7 **
volume (ml) required for 100 kg bear[d]	4.9	2.5
time (min)	9.5±1.8	6.5±1.0
number of bears requiring top-up dose	4 (or 24%)	1 (or 10%)
time between first injection and top-up injection (min)	35.8±3.0	27
2. Reversal		
reversible?	no	yes
drug for reversal		yohimbine
dose (mg)[e]		23±3
dosage (mg/kg)		0.18±0.02
time to reversal (min)[f]		12.7±2.8

[a] Four bears (one with ZT and three with XZT) were captured in Banff National Park during June, 1999, in a program that was independent of the Foothills Model Forest Grizzly Bear Project.

[b] Values presented as mean ± SE unless indicated otherwise. Where possible, drug groups were compared by a t-test for two independent samples and statistical significance is indicated by * for $p < 0.05$ and ** for $p < 0.01$.

[c] Body mass was determined for eight bears anesthetized with ZT, and seven bears anesthetized with XZT.

[d] Both drugs were similarly concentrated at 227 mg/ml. ZT was prepared in solution by adding 1.8 ml of sterile water to 500 mg (one vial) of lyophilized Telazol®. XZT was prepared in solution by adding 3.3 ml of xylazine solution (100 mg/ml) to 500 mg (one vial) of lyophilized Telazol®. The weight:weight ratio of xylazine to Telazol® in XZT was 2:3.

[e] Injected in a 2 mg/ml solution with ½ of the reversal volume given by intravenous injection, and ½ of the reversal volume given by intramuscular injection.

[f] Indicates time from injection of reversal drug until bear was able to raise head and shoulders, and appeared fully aware of handling personnel.

Table 2. Serum biochemistry reference ranges for grizzly bears captured for the Foothills Model Forest (FMF) Grizzly Bear Project during May and June 1999, and for grizzly bears captured during two previous projects in other geographical locations.[a]

Serum parameter	Location and Year Alberta (1999) $n = 18$	Yukon (1969) $n = 13$	Alaska (1973-82) $n = 78 - 155$
sodium (mmol/L)	136 - 154	129 - 161	114 - 156
potassium (mmol/L)	3.2 - 4.6	3.1 - 5.1	3.1 - 5.7
chloride (mmol/L)	99 - 122	92 - 120	76 - 120
bicarbonate (mmol/L)	6 - 27	na	2 - 26
anion gap (mmol/L)	12 - 31	na	na
calcium (mmol/L)	1.97 - 2.53	2.24 - 2.94	0.80 - 3.40
phosphorus (mmol/L)	0.88 - 2.10	0.75 - 2.55	0.61 - 2.29
urea (mmol/L)	1.0 - 21.4	0.0 - 29.1	3.5 - 22.9
creatinine (µmol/L)	14 - 189	0 - 246	44 - 120
U/C ratio	5.1 - 53.4	na	na
glucose (mmol/L)	3.1 - 10.3	4.4 - 7.6	1.8 - 9.0
cholesterol (mmol/L)	4.07 - 7.36	4.20 - 9.92	2.41 - 8.39
total bilirubin (µmol/L)	0 - 10	0 - 8	0 - 4
amylase (U/L)	0 - 230	na	na
alkaline phosphatase (U/L)	0 - 120	0 - 67	0 - 153
alanine aminotransferase (U/L)	0 - 153	na	0 - 207
γ-glutamyltransferase (U/L)	0 - 48	na	na
creatine kinase (U/L)	0 - 14266	na	na
total protein (g/L)	61 - 81	61 - 81	40 - 79
albumin (g/L)	34 - 48	32 - 52	22 - 58
globulin (g/L)	22 - 38	na	15 - 41
A/G ratio	0.94 - 1.82	na	0.58 - 1.88
lipase (U/L)	73 - 516	na	na
total cortisol (nmol/L)	3 - 1302	na	249 - 727

[a] Data from southwestern Yukon reported by Halloran and Pearson in 1972 (Canadian Journal of Zoology 50: 827-833) and data from north-central Alaska reported by Brannon in 1985 (Journal of Wildlife Management 49: 893-900). Reference ranges represent values from (mean - 2SD) to (mean + 2SD) and 'na' indicates data was not available.

Table 3. Serum biochemistry of grizzly bears captured by leg-hold snare and by aerial-darting for the Foothills Model Forest Grizzly Bear Project during May and June 1999. Bears were anesthetized with either Telazol® (ZT) or a combination of xylazine and Telazol® (XZT).[a]

Serum parameter	ZT		XZT	
	snare ($n = 9$)	aerial ($n = 3$)	snare ($n = 4$)	aerial ($n = 2$)
sodium (mmol/L) †	138 - 151	140 - 141	141 - 151	141-143
potassium (mmol/L)	3.2 - 4.3	3.2 - 4.2	3.7 - 4.6	3.8 - 4.3
chloride (mmol/L) †	107 - 120	100 - 106	108 - 115	100 - 110
bicarbonate (mmol/L)	10 - 24	11 - 19	14 - 21	17 - 28
anion gap (mmol/L)	13 - 30	19 - 30	19 - 20	17 - 21
calcium (mmol/L) †	1.96 - 2.49	2.25 - 2.40	1.98 - 2.30	2.34 - 2.38
phosphorus (mmol/L)	0.94 - 1.75	1.70 - 2.22	1.31 - 1.71	1.36 - 1.85
urea (mmol/L)	6.6 - 18.9	8.4 - 17.3	4.9 - 17.4	12.5 - 23.9
creatinine (μmol/L) †	63 - 123	103 - 249	79 - 86	74 - 147
U/C ratio	18.4 - 41.7	8.3 - 41.4	14.1 - 53.7	40.1 - 41.7
glucose (mmol/L)	3.1 - 8.5	5.4 - 7.9	7.0 - 9.9	4.7 - 5.8
cholesterol (mmol/L)	4.87 - 7.68	4.99 - 6.18	4.16 - 6.29	5.60 - 6.35
total bilirubin (μmol/L)	2 - 12	3 - 3	4 - 8	4 - 9
amylase (U/L)	16 - 378	32 - 58	14 - 26	7 - 45
alkaline phosphatase (U/L)	20 - 104	21 - 130	21 - 45	46 - 110
alanine aminotransferase (U/L) †	46 - 164	24 - 43	29 - 67	22 - 63
γ-glutamyltransferase (U/L)	9 - 60	17 - 28	11 - 20	19 - 20
creatine kinase (U/L) †	144 - 26020	112 - 235	244 - 1752	53 - 391
total protein (g/L)	63 - 80	62 - 76	69 - 75	67 - 71
albumin (g/L)	34 - 48	37 - 40	35 - 44	39 - 41
globulin (g/L)	23 - 35	25 - 36	28 - 38	26 - 32
A/G ratio	1.03 - 1.81	1.13 - 1.49	0.90 - 1.48	1.24 - 1.56
lipase (U/L) †	158 - 525	108 - 308	238 - 398	155 - 193
total cortisol (nmol/L)	213 - 1227	531 - 714	431 - 1079	114 - 589

[a] Values reported as range from minimum to maximum value.

† Significant differences ($p < 0.05$) between serum concentrations for parameters in bears captured by leg-hold snare and in bears captured by aerial-darting were indicated by the Mann-Whitney U-test. Parameters with greater serum concentrations in bears captured by leg-hold snare included sodium, chloride, alanine aminotransferase, creatine kinase, and lipase. Parameters with greater serum concentrations in bears captured by aerial-darting included calcium and creatinine.

Table 4. Health assessment of individual grizzly bears captured for the Foothills Model Forest Grizzly Bear Project during May and June 1999 based on body condition index (BCI) and serum biochemistry.

Bear	Capture Date (method / drug)	Health Assessment
G2	05/04 (aerial / Telazol®)	• high phosphorus (2.22 mmol/L) and creatinine (249 µmol/L) is consistent with decreased urinary excretion. This is probably due to recent arousal from winter dormancy as suggested by date of capture and by low U/C ratio (8.3).
G3	05/09 (aerial / Telazol®)	• high alkaline phosphatase (130 U/L), but probably not of any consequence to health.
G4	05/10 (aerial / XZT)	• high urea (23.9 mmol/L) and mildly elevated creatinine (147 µmol/L) suggest decreased renal function. High bicarbonate (28 mmol/L), low potassium (3.2 mmol/L), and low chloride (100 mmol/L) is consistent with mild metabolic alkalosis (which most often occurs following vomiting).
G5	05/11 (snare / XZT)	• poor body condition relative to other bears captured during spring. High globulin (38 g/L) and low A/G ratio (0.90) possibly associated with hemolysis of blood sample
G7	05/19 (snare / XZT)	• high creatine kinase (CK) (1752 U/L) and high alanine aminotransferase (ALT) (64 U/L) is consistent with muscle damage. High cortisol (887 nmol/L) suggests stress. High glucose (mmol/L) could be caused by stress, or xylazine, or both stress and xylazine.
G8	05/14 (aerial / Telazol®)	• high glucose (7.9 mmol/L) is consistent with stress.
G9	05/20 (snare / Telazol®)	• high glucose (8.5 mmol/L) suggests stress. High CK (1399 U/L) and high ALT (62 U/L) is consistent with muscle damage.
G11	05/09 (snare / Telazol®)	• high hematocrit (0.661 L/L) and high total protein (80 g/L), with normal A/G ratio (1.55), is consistent with loss of extracellular fluid (dehydration). High CK (4560 U/L) and high ALT (132 U/L) is consistent with muscle damage. High cortisol (964 nmol/L) suggests stress.
G11	05/19 (snare / XZT)	• high glucose (9.9 mmol/L) could be caused by stress, or xylazine, or both stress and xylazine. High CK (1128 U/L) and high ALT (67 U/L) is consistent with muscle damage.

G12	05/26 (snare / Telazol®)	• low calcium (1.96 mmol/L) and low glucose (3.1 mmol/L) may be artefacts of prolonged time between blood collection and plasma separation. High hematocrit (0.581 L/L), low sodium (138 mmol/L), and low potassium (3.2 mmol/L) are consistent with loss of extracellular fluid (dehydration), but loss of sodium suggests fluid loss through gastric secretion (e.g., diarrhea) rather than insensible water loss (e.g., panting). High CK (1058 U/L) and high ALT (75 U/L) is consistent with muscle damage. High white blood cell count (25.5×10^{9} L^{-1}), low globulin (23 g/L), and high A/G ratio (1.81) suggest the possibility of concurrent disease (viral or bacterial). High cortisol (1107 nmol/L) suggests stress.
G13	05/27 (snare / Telazol®)	• high γ-glutamyltransferase (GGT) (60 U/L) is consistent with suppression or stoppage of bile flow (possibly as a result of liver disease). High ALT (117 U/L) is also consistent with liver damage rather than muscle damage (as CK value is normal at 282 U/L). High cholesterol (7.68 mmol/L) could occur secondary to liver disease. High cortisol (927 nmol/L) is consistent with stress.
G14	06/06 (snare / Telazol®)	• high glucose (7.7 mmol/L) and high cortisol (1227 nmol/L) are consistent with stress. Markedly elevated CK (26,020 U/L) and high ALT (164 U/L) are consistent with significant muscle injury.
G16	05/28 (aerial / XZT)	• no abnormal findings
G17	05/28 (snare / XZT)	• high cortisol (1079 nmol/L) is consistent with stress. High glucose (8.3 mmol/L) may be caused by stress, or xylazine, or both stress and xylazine.
G18	05/29 (snare / Telazol®)	• no abnormal findings
G19	06/02 (snare / Telazol®)	• high glucose (8.3 mmol/L) is consistent with stress.
G20	06/13 (snare / Telazol®)	• high anion gap (30 mmol/L) is likely an artefact of sample handling (i.e., *in vitro* loss of bicarbonate)
G21	06/20 (snare / Telazol®)	• high GGT (46 U/L) is consistent with suppression or stoppage of bile flow (possibly as a result of liver disease). High ALT (105 U/L) is also consistent with liver damage rather than muscle damage (as CK value is normal at 144 U/L).

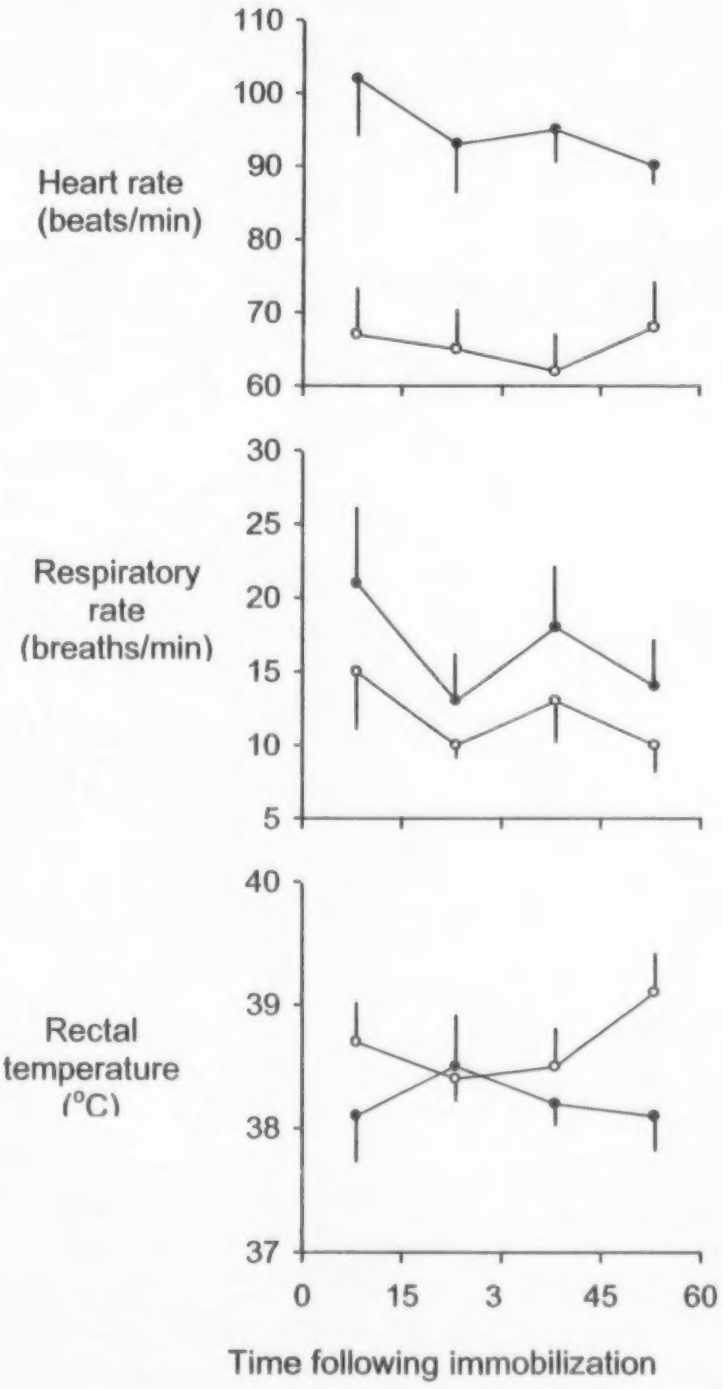

Figure 1. Physiologic response of 27 grizzly bears during anesthesia with ZT (●, n =17) and XZT (○, n = 10). Values are presented as the mean + or - the standard error of values measured within 15 minute intervals subsequent to the time of complete immobilization.

Appendix B

Televilt Measuring Schedule

Appendix B. Televilt measuring schedule 1999 (local standard time).

Females					Males				
G020	G013	G004	G002	G019	G001	G005	G006	G008	G016
2:00	0:30	0:30	2:30	1:30	1:00	3:00	0:10	1:00	3:30
6:00	4:30	4:30	6:30	5:30	5:00	7:00	4:00	5:00	7:30
10:00	8:30	8:30	10:30	9:30	9:00	11:00	8:00	9:00	11:30
14:00	12:30	12:30	14:30	13:30	13:00	15:00	12:00	13:00	15:30
18:00	16:30	16:30	18:30	17:30	17:00	19:00	16:00	17:00	19:30
22:00	20:30	20:30	22:30	21:30	21:00	23:00	20:00	21:00	23:30

Appendix C

Goodness of fit test from CAPTURE for grizzly bear dataset generated from baited hair removal sites

Goodness of fit tests from CAPTURE for the grizzly bear dataset generated from baited hair removal sites.

```
Mark-recapture population and density estimation program
Page   2
                                   Program version of 13 Jul 1991
14-Feb-**

Model selection procedure.  See this section of the Monograph for
details.

Occasion            j=     1    2    3
Animals caught   n(j)=    16   22   10
Total caught     M(j)=     0   16   33   40
Newly caught     u(j)=    16   17    7
Frequencies      f(j)=    33    6    1

1. Test for heterogeneity of trapping probabilities in population.
   Null hypothesis of model  M(o)  vs. alternate hypothesis of model
M(h)

          Expected values too small.  Test not performed.

2. Test for behavioral response after initial capture.
   Null hypothesis of model  M(o)  vs. alternate hypothesis of model
M(b)

          Chi-square value =    1.376   degrees of freedom =   1
                     Probability of larger value =  0.24072

3. Test for time specific variation in trapping probabilities.
   Null hypothesis of model  M(o)  vs. alternate hypothesis of model
M(t)

          Chi-square value =    5.921   degrees of freedom =   2
                     Probability of larger value =  0.05179

4. Goodness of fit test of model  M(h)
   Null hypothesis of model  M(h) vs. alternate hypothesis of not model
M(h)

          Chi-square value =    5.538   degrees of freedom =   2
                     Probability of larger value =  0.06271

          Test of model M(h) by frequency of capture
          (frequencies less than 2t are not calculated.)

          Number of captures  Chi-square  d.f.  Probability
          ------------------------------------------------
                  1              2.909     2      0.23351
                  2              4.000     2      0.13534


5. Goodness of fit test of model  M(b)
   Null hypothesis of model  M(b) vs. alternate hypothesis of not model
M(b)
```

Chi-square value = 6.105 degrees of freedom = 2
Probability of larger value = 0.04723

5a. Contribution of first capture homogeneity across time

Chi-square value = 2.232 degrees of freedom = 1
Probability of larger value = 0.13515

5b. Contribution of recapture homogeneity across time

Chi-square value = 3.873 degrees of freedom = 1
Probability of larger value = 0.04907

6. Goodness of fit test of model M(t)
Null hypothesis of model M(t) vs. alternate hypothesis of not model M(t)

Expected values too small. Test not performed.

7. Test for behavioral response in presence of heterogeneity.
Null hypothesis of model M(h) vs. alternate hypothesis of model M(bh)

Chi-square value = 2.909 degrees of freedom = 2
Probability of larger value = 0.23351

Model selection criteria. Model selected has maximum value.

Model	M(o)	M(h)	M(b)	M(bh)	M(t)	M(th)	M(tb)	M(tbh)
Criteria	1.00	0.69	0.00	0.60	0.16	0.84	0.29	0.79

Appropriate model probably is M(o)
Suggested estimator is null.

Test for closure procedure. See this section of the Monograph for details.

Overall test results --	
z-value	-1.732
Probability of a smaller value	0.04163

Table 4. Grizzly bear population estimates from 8 closed mark-recapture models in program CAPTURE based on DNA analysis of hair collected at bait sites during summer 1999 for the Jasper Park-Hinton area of Alberta.

Model	$\hat{N}$	SE	95% CI
M_o-Null	81	19.6	54-145
M_h-Jackknife	70	7.9	58-90
M_h-Chao	113	38.8	67-234
M_t-Darroch	77	17.8	52-138
M_t-Chao	80	21.2	55-145
M_{th}-Chao	109	58.1	56-329
M_b-Zippin	52	10.4	41-162
M_{bh}-Removal	52	10.4	41-162

Appendix D

Goodness of fit tests from CAPTURE for the hair removal and live capture combined datasets

Goodness of fit tests from CAPTURE for the hair removal and live capture combined dataset.

```
Mark-recapture population and density estimation program
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                                   Program version of 13 Jul 1991
14-Feb-**

Model selection procedure.  See this section of the Monograph for
details.

Occasion           j=     1    2    3    4
Animals caught   n(j)=    15   22   23   10
Total caught     M(j)=     0   15   31   42    48
Newly caught     u(j)=    15   16   11    6
Frequencies      f(j)=    33    9    5    1

1. Test for heterogeneity of trapping probabilities in population.
   Null hypothesis of model  M(o)  vs. alternate hypothesis of model
M(h)

          Chi-square value =    4.341   degrees of freedom =   1
                     Probability of larger value =  0.03722

2. Test for behavioral response after initial capture.
   Null hypothesis of model  M(o)  vs. alternate hypothesis of model
M(b)

          Chi-square value =    0.019   degrees of freedom =   1
                     Probability of larger value =  0.88915

3. Test for time specific variation in trapping probabilities.
   Null hypothesis of model  M(o) . vs. alternate hypothesis of model
M(t)

          Chi-square value =    9.951   degrees of freedom =   3
                     Probability of larger value =  0.01899

4. Goodness of fit test of model  M(h)
   Null hypothesis of model  M(h) vs. alternate hypothesis of not model
M(h)

          Chi-square value =    9.040   degrees of freedom =   3
                     Probability of larger value =  0.02877

          Test of model M(h) by frequency of capture
          (frequencies less than 2t are not calculated.)

          Number of captures  Chi-square  d.f.  Probability
          ------------------------------------------------

                  1               3.970     3      0.26476
                  2               8.333     3      0.03961

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```

5. Goodness of fit test of model M(b)
Null hypothesis of model M(b) vs. alternate hypothesis of not model M(b)

Chi-square value = 11.722 degrees of freedom = 4
Probability of larger value = 0.01955

5a. Contribution of first capture homogeneity across time

Chi-square value = 1.449 degrees of freedom = 2
Probability of larger value = 0.48458

5b. Contribution of recapture homogeneity across time

Chi-square value = 10.273 degrees of freedom = 2
Probability of larger value = 0.00588

6. Goodness of fit test of model M(t)
Null hypothesis of model M(t) vs. alternate hypothesis of not model M(t)

Expected values too small. Test not performed.

7. Test for behavioral response in presence of heterogeneity.
Null hypothesis of model M(h) vs. alternate hypothesis of model M(bh)

Chi-square value = 4.081 degrees of freedom = 4
Probability of larger value = 0.39518

Model selection criteria. Model selected has maximum value.

Model	M(o)	M(h)	M(b)	M(bh)	M(t)	M(th)	M(tb)	M(tbh)
Criteria	0.66	0.48	0.00	0.08	0.65	1.00	0.04	0.52

Appropriate model probably is M(th)
Suggested estimator is Chao's M(th).

Test for closure procedure. See this section of the Monograph for details.

Overall test results --

z-value	-1.562
Probability of a smaller value	0.05910

Table 5. Grizzly bear population estimates from 8 closed mark-recapture models in program CAPTURE based on DNA analysis of hair collected at bait sites during summer 1999 and live capture of 22 bears for the Jasper Park-Hinton area of Alberta.

Model	$\hat{N}$	SE	95% CI
M_o-Null	69	9.0	55-93
M_h-Jackknife	91	11.0	74-118
M_h-Chao	108	30.2	72-200
M_t-Darroch	68	8.2	55-90
M_t-Chao	87	19.5	63-146
M_{th}-Chao	118	34.7	76-223
M_b-Zippin	67	15.8	51-268
M_{bh}-Removal	67	15.8	51-268